

GIANT 2002 NEW CAR AND TRUCK GUIDE

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OCTOBER 2001

Popular Mechanics

**BEST
PORTABLE
TABLE SAW**

JET TRAVEL AT THE SPEED OF SOUND

Boeing's Sonic Cruiser Opens A
New Era Of Commercial Aviation

GUN FINGERPRINTS

Latest Weapon In The
War On Crime

MP3 CAR AUDIO

Newest Way To
Rock And Roll

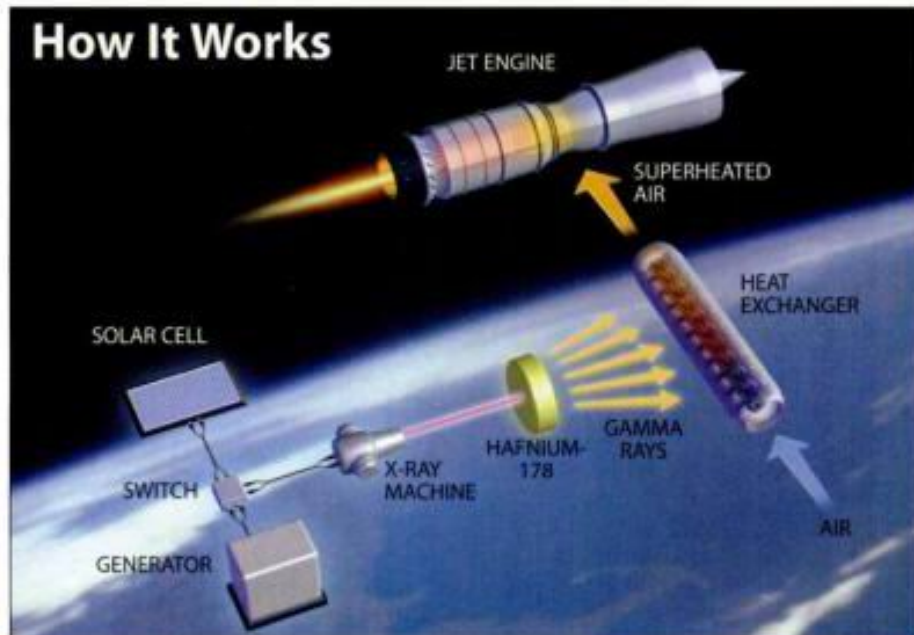
CLEANEST, QUIETEST PWC EVER

Yamaha's New 4-Stroke
WaveRunner Sizzles



\$3.50

How It Works



A solar cell or engine-mounted generator sends electricity to run a small X-ray machine. The X-rays strike a block of hafnium-178, triggering a drop in the energy levels within the nucleus of the hafnium atoms. This change in energy levels is accompanied by the release of a burst of gamma radiation. The gamma rays heat the core of a heat exchanger. Superheated air from the exchanger floods into the jet engine, performing the same function as the expanding gases created by burning jet fuel. For safety reasons, conventional jet fuel will power the engine when it is below cruising altitude.

In this area, which will be designed to minimize leakage of radiation, engineers will install the world's first airborne quantum nucleonic reactor.

Flying Nukes

A jet engine is the essence of mechanical simplicity. Fuel and

air are mixed, compressed and ignited. As the gas burns, it moves rapidly rearward, propelling the aircraft forward. Normally, this is done by burning jet fuel, which is exactly what the new nuclear plane will do when it takes off, climbs and lands. When it reaches cruising

altitude—in the vicinity of 45,000 ft. and above trans-Atlantic airline traffic—the engine will switch over to running on hot air created by the reactor. Using this power source, an unmanned version could remain on station for months on end. A manned version, the logical next step, could operate as long as the crew had food.

Building a nuclear aircraft poses daunting engineering challenges. The underlying operating principle, however, is straightforward. In a fission reactor, atoms of a very heavy element, such as uranium, are persuaded to split apart, casting off neutrons that split other atoms and produce heat. In a fusion reactor, atoms of a very light element, such as hydrogen, are cajoled to join. Here, too, the conversion of mass into energy obeys the tenets of Einstein's famous $E=mc^2$ equation. The immense heat release keeps the reaction going.

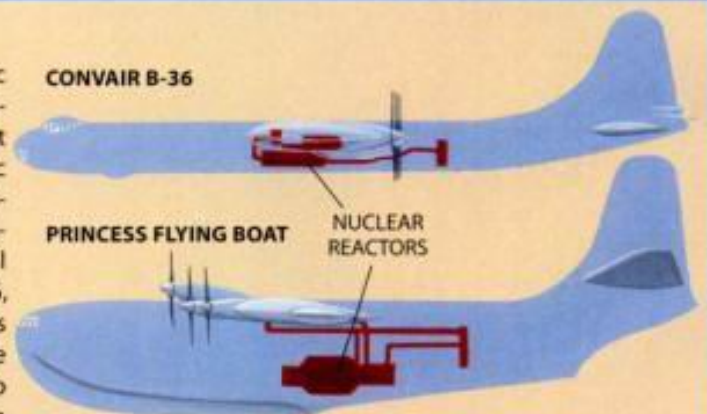
Fusion reactors are in their infancy. But as early as 1940, scientists were thinking about ways of using the heat from nuclear

Earlier Attempts

Older *POPULAR MECHANICS* readers may recall that an atomic plane was featured as our January 1941 cover story. Conceived by physicists at the California Institute of Technology, it used a fission reactor similar to those now used by electric utilities. The idea was put on the shelf during the war years. "Aircraft nuclear power became an official research project in May 1946, when the Army Air Forces awarded to the Fairchild Engine and Airplane Corp. a contract to perform preliminary studies on a manned, nuclear-propelled airplane," explains Carolyn C. James, a historian who has studied the military's nuclear flight program. In December 1957, the Navy proposed turning a British-made Princess Flying Boat into a nuclear aircraft by connecting its 10 PW T-57 engines to

CONVAIR B-36

PRINCESS FLYING BOAT
NUCLEAR REACTORS



a modified General Electric direct-cycle reactor. The Air Force set its sights on converting a B-36 bomber.

The Navy plane never flew off the drawing board. The Air Force got as far as ground testing jet engines and, in a separate airborne test, operated a reactor in a flying aircraft. Both projects were eventually canceled, chiefly because they required too much radiation shielding to protect air crews.

SCIENCE

ATOMIC

A new mini-reactor revives the dream of a nuclear-powered aircraft.

BY JIM WILSON



WINGS



After more than six decades of research, the first atom-powered airplane is cleared for takeoff. Although details of the project remain classified, a description of this remarkable aircraft has begun to emerge from technical conferences and declassified engineering studies. The plane will be both familiar and unique. Familiar in that it will resemble a Northrop Grumman

AVIATION

Global Hawk, the bulbous-nosed unmanned aerial vehicle (UAV) that the U.S. Air Force has used to track enemy movements in Afghanistan and Iraq. Unique because its nuclear reactor is unlike any other. Rather than split heavy elements or fuse light atoms—as in fission and fusion reactors—it will use what is known as a triggered isomer reaction. If this new powerplant, called a quantum delayed isomer reactor, performs as scientists expect, its effect on the aircraft industry may prove as revolutionary as the introduction of the jet engine.

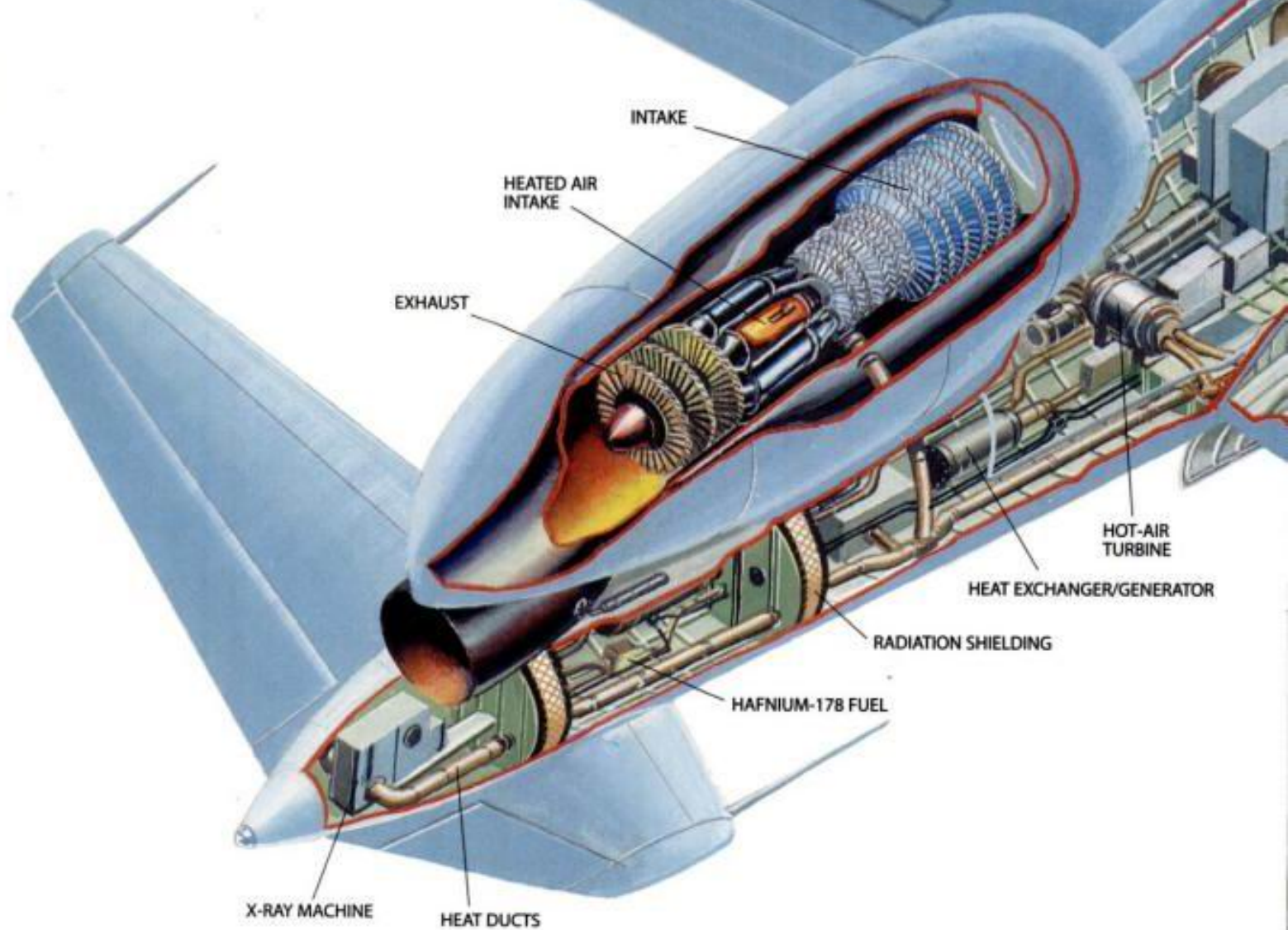
The new hafnium-fueled reactor emits so little radiation it could be easily integrated into civilian airport operations.

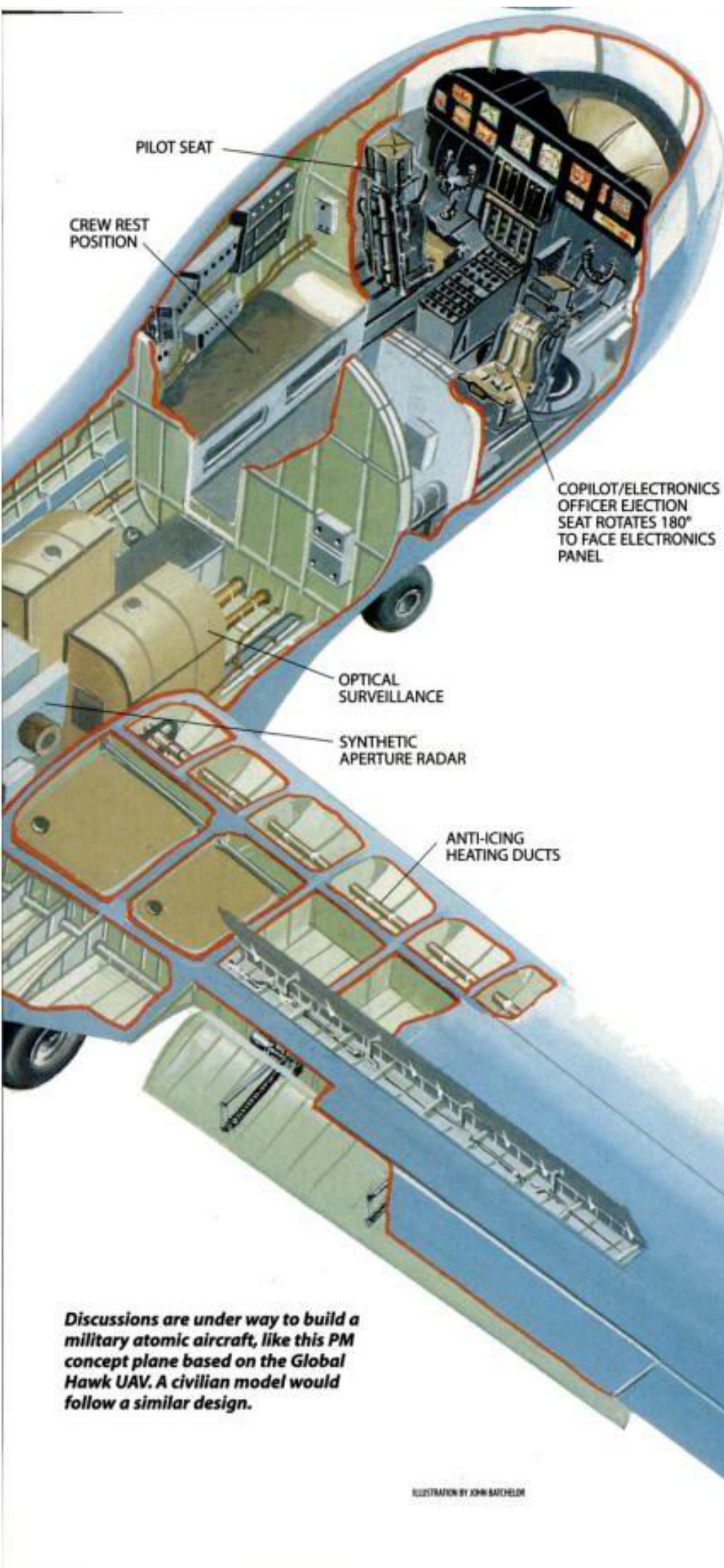
Ungainly Elegance

To the trained eye, the ungainly Global Hawk is a thing of beauty. A triumph of function over form, its whale-snout nose presents a tiny radar cross sec-

ILLUSTRATION BY PAUL DUNN

Inside The Nuclear Plane





PILOT SEAT

CREW REST
POSITION

COPILOT/ELECTRONICS
OFFICER EJECTION
SEAT ROTATES 180°
TO FACE ELECTRONICS
PANEL

OPTICAL
SURVEILLANCE

SYNTHETIC
APERTURE RADAR

ANTI-ICING
HEATING DUCTS

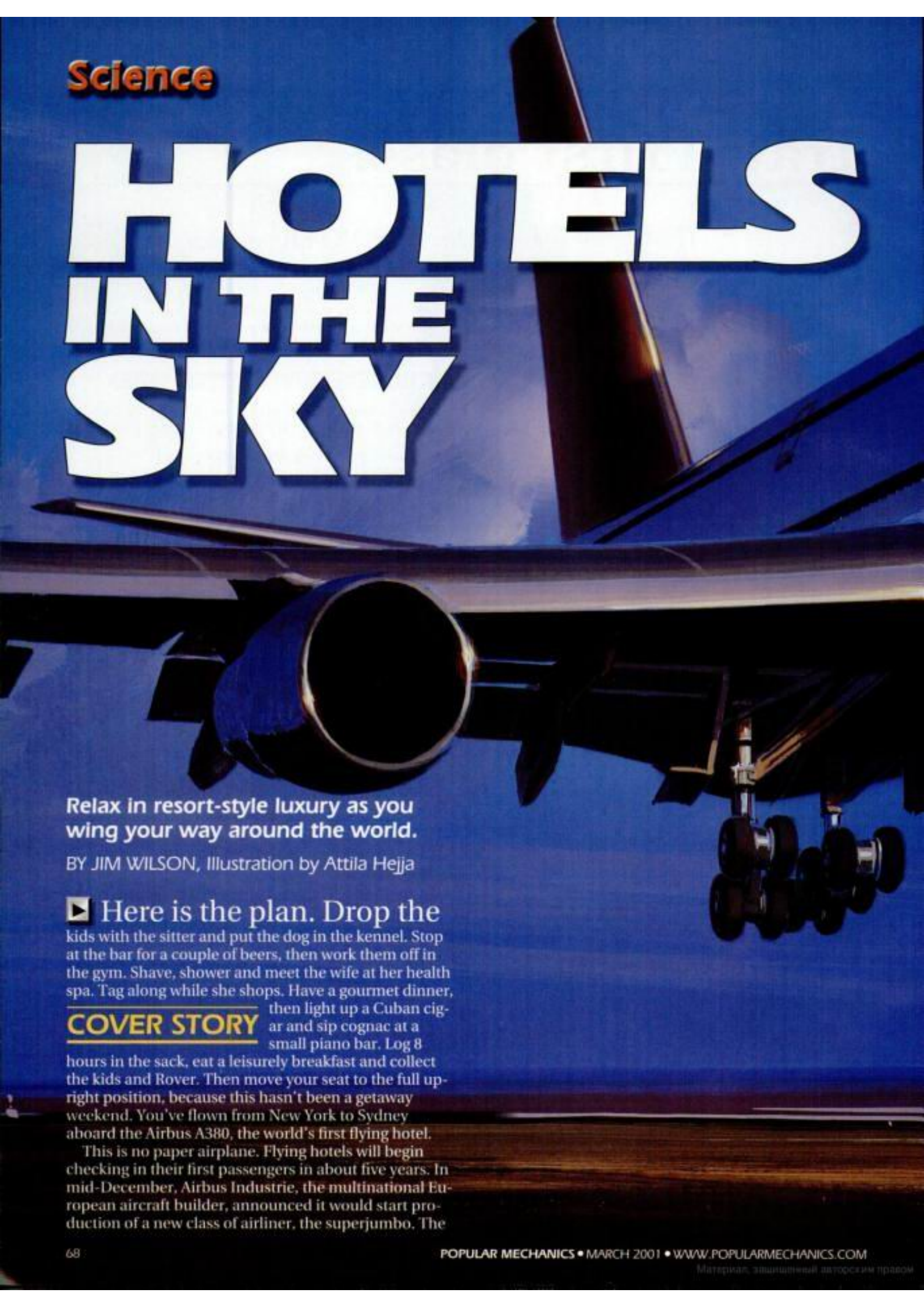
tion. The thickly shrouded rear-mounted engine, located high in the tail, presents a minimal heat signature. Even the paint, which appears faded, serves a purpose: It helps dissipate heat from the plane's electronic bay. Together, these design features make the Global Hawk virtually invisible as it loiters at 45,000 ft., directing its powerful radar and high-resolution cameras on trouble spots.

One improvement would make the Global Hawk the perfect surveillance platform: eliminating the need to top off its fuel tanks. For UAVs operating deep within hostile airspace, refueling requires dashing hundreds, sometimes thousands, of miles to a friendly landing field. It is chiefly for that reason that the Global Hawk has been selected as a test-bed for one of the boldest experiments in aviation history. Project managers for Northrop Grumman and the U.S. Air Force Research Laboratory tell *POPULAR MECHANICS* they have begun discussions that could lead to the conversion of a Global Hawk to a nuclear-powered aircraft.

If the plan takes shape, a Global Hawk will be pulled off the production line and undergo extensive airframe and power-plant modifications. Chief among these will be the addition of some 2700 pounds of radiation shielding. Installed between the tail section and the main electronics bay, the shielding will create a "hot cell."

Discussions are under way to build a military atomic aircraft, like this PM concept plane based on the Global Hawk UAV. A civilian model would follow a similar design.

ILLUSTRATION BY JOHN BACHELOR



Science

HOTELS IN THE SKY

Relax in resort-style luxury as you wing your way around the world.

BY JIM WILSON, Illustration by Attila Hejja

► Here is the plan. Drop the kids with the sitter and put the dog in the kennel. Stop at the bar for a couple of beers, then work them off in the gym. Shave, shower and meet the wife at her health spa. Tag along while she shops. Have a gourmet dinner, then light up a Cuban cigar and sip cognac at a small piano bar. Log 8 hours in the sack, eat a leisurely breakfast and collect the kids and Rover. Then move your seat to the full upright position, because this hasn't been a getaway weekend. You've flown from New York to Sydney aboard the Airbus A380, the world's first flying hotel.

This is no paper airplane. Flying hotels will begin checking in their first passengers in about five years. In mid-December, Airbus Industrie, the multinational European aircraft builder, announced it would start production of a new class of airliner, the superjumbo. The

COVER STORY



"Placing the cockpit between the top decks puts the pilot's eyes at the same height as an existing jumbo."

first, the A380, will fly off an assembly line in France in the fall of 2004, and customers will begin taking delivery in the winter of 2006. The first orders are for 555-passenger models. The largest jumbo jet currently in service is the 413-seat Boeing 747-400. It is a striking increase in the number of seats. But what is most impressive about the A380 is all the empty space.

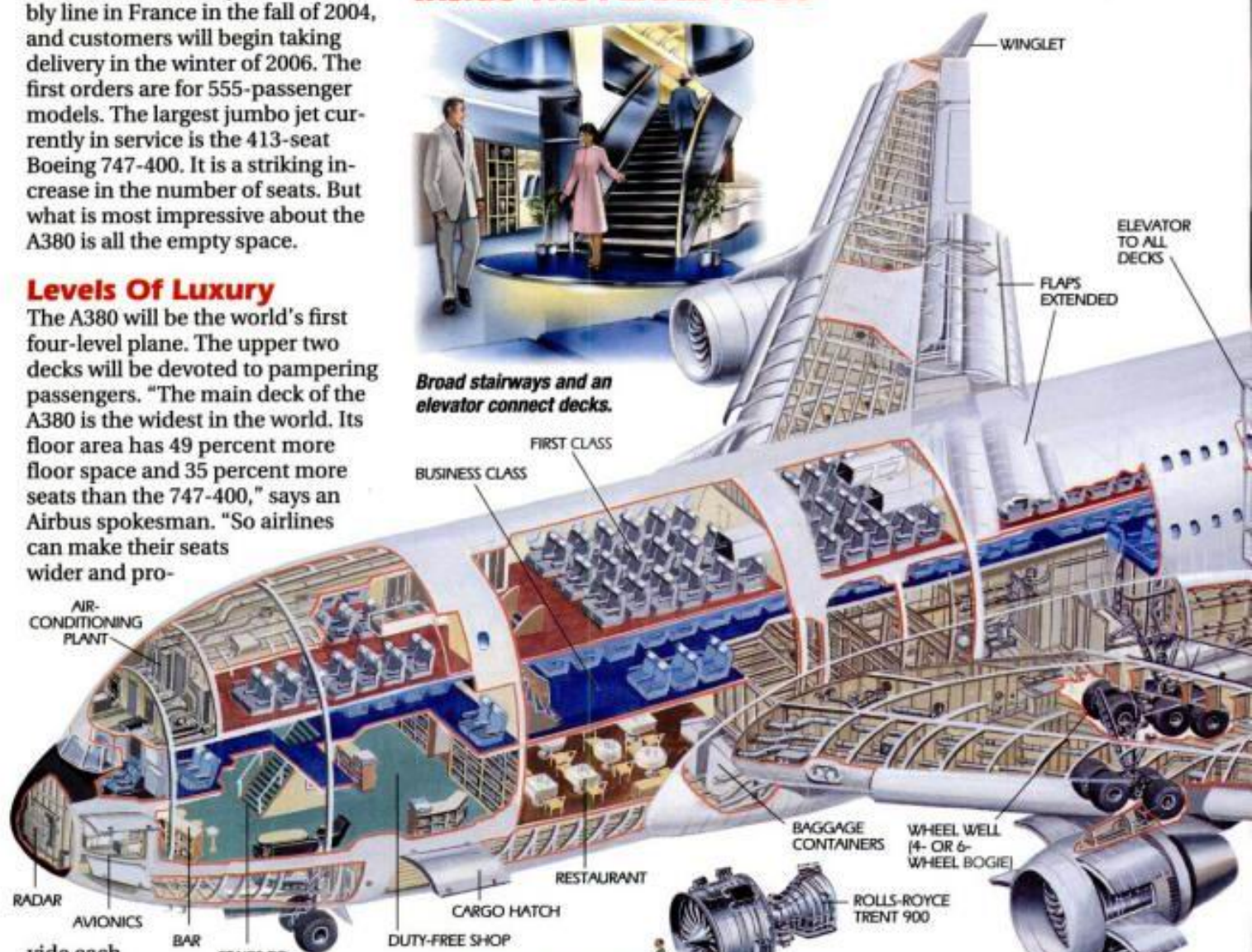
Levels Of Luxury

The A380 will be the world's first four-level plane. The upper two decks will be devoted to pampering passengers. "The main deck of the A380 is the widest in the world. Its floor area has 49 percent more floor space and 35 percent more seats than the 747-400," says an Airbus spokesman. "So airlines can make their seats wider and pro-

Inside The Airbus A380



Broad stairways and an elevator connect decks.



vide each seat with its own separate armrest—a frequent passenger demand."

To create the space, the A380 will be longer and fatter than any other commercial airliner, but most striking, it will be taller. This means that even in the versions configured for maximum seating, an entire level will be available for sleeper cabins, crew rest areas, a business center and a nursery. The exact accommodations in the planes will be determined by their owners. At its press conference in December, Airbus announced that it had a total of 50 orders from six of the major players in the international air transport industry: Air France, Emirates, International Lease Finance Corp., Qantas, Singapore Airlines and Virgin Atlantic.

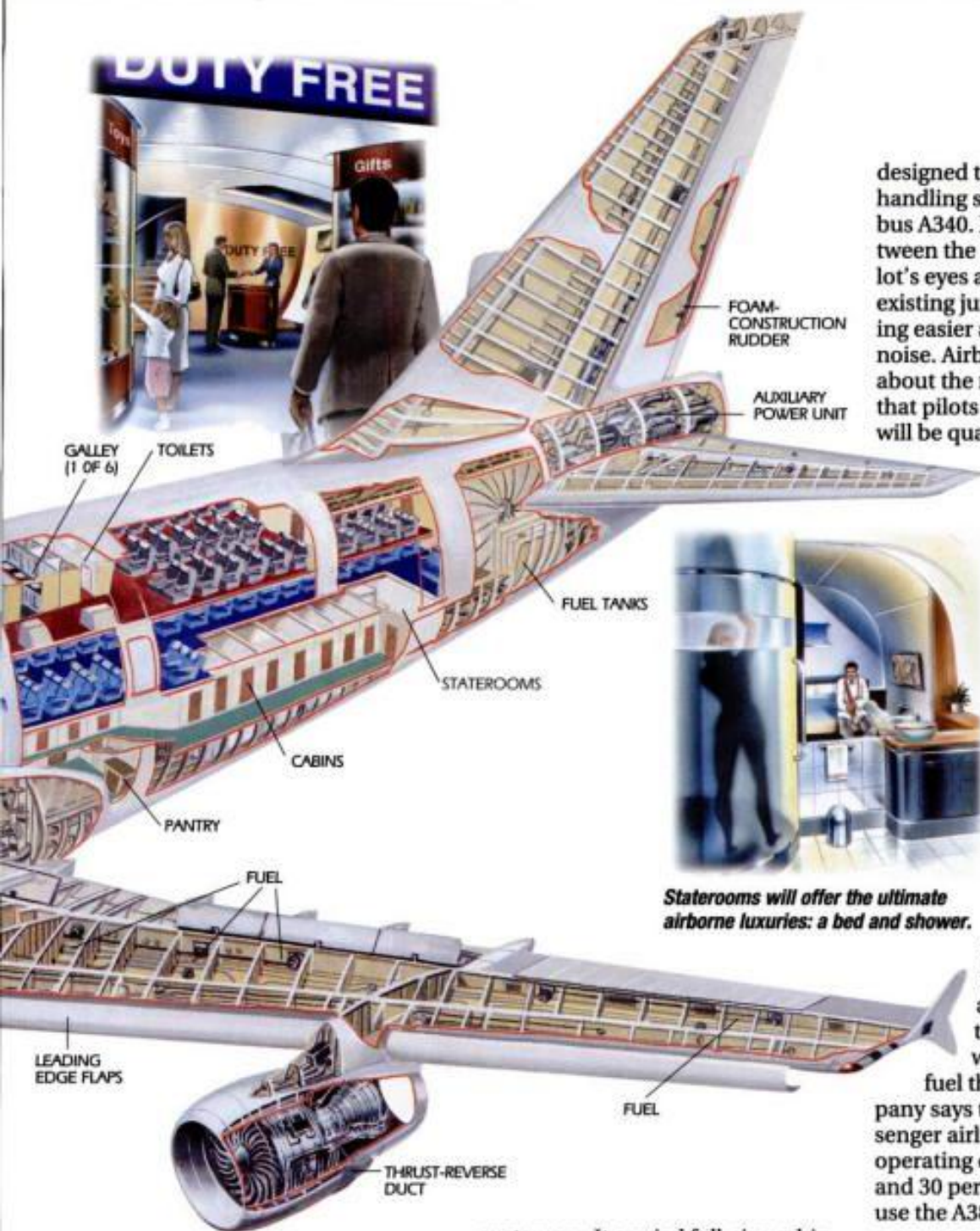


Single-serving wine bottles are out. The flying hotel's bar will stock a fine cellar.

In addition to selecting the interior, airlines will also be able to choose the powerplant. Airbus has designed the A380 to fly using either a Rolls-Royce Trent 900 or an

Engine Alliance GP 7200. As you might imagine, it will take a considerable amount of power to get the A380 off the ground. Airbus estimates that the plane's takeoff weight will be nearly 1.2 billion pounds. Both manufacturers say they can produce turbofan engines certified to deliver 75,000 pounds of thrust. By way of comparison, the Pratt & Whitney JT3 turbojets on the original Boeing 707—the plane that started the jet travel revolution—were rated at 10,000 pounds.

Each A380 will cost about \$216 million, which Airbus says will be a true bargain for airlines. The company calculates that compared to a \$185 million Boeing 747-400, the A380 costs 13 percent less per seat to buy and to fuel.



designed to make the new aircraft's handling similar to the smaller Airbus A340. Placing the cockpit between the top two decks puts the pilot's eyes at the same height as an existing jumbo. This will make taxiing easier and also reduce cockpit noise. Airbus expects that so much about the new plane will be familiar that pilots of existing A340 jumbos will be qualified to fly the A380 superjumbo after 12 days of training, less than half the time required with other aircraft.

Forgeard says that Airbus has been working closely with 50 major airports to ensure that the A380 will be welcome when it takes off and lands. One of the major requirements by airport executives had to do with noise.

Airbus says the computer models it used to design the plane suggest it will be one of the most environmentally friendly aircraft ever to take to the sky. For example, it will burn 20 percent less fuel than a 747-400. The company says that for operators of passenger airlines, this will lower cash operating costs by about 17 percent, and 30 percent for operators who use the A380 for freight service.

Staterooms will offer the ultimate airborne luxuries: a bed and shower.

What Flyers Want

Introducing an airliner is always a risky business. You don't see many Douglas DC-10 and Lockheed L-1011 jumbos in passenger service these days. And the companies that built them are now parts of other corporations. Because aircraft are so enormously expensive to design, you need to sell significant numbers to stay in business. Airbus accountants say the company will need to sell 250 of its new superjumbos to break even on its investment in research, development and production.

To insulate itself against a corporate catastrophe, Airbus took the unusual step of test marketing its superjumbos with its customers'

customers. It carried full-size cabin mockups to eight major cities on three continents and conducted in-depth interviews with 1200 frequent flyers. "We designed this aircraft not just for our customers, but with them," says Airbus's chief executive officer, Noël Forgeard.

Airbus put similar effort into pleasing the single most important person on any airliner, the pilot. "Considerable ergonomics research was undertaken, with pilots of many major airlines contributing to the final design," says an Airbus executive. For this reason, the plane's cockpit instrumentation is similar to but more advanced than that found on existing Airbus flight decks. Controls have been

Cleared For Landing

The A380 has also cleared the three hurdles set up by government regulators: noise, safety and fit. "It will be the only widebody that meets the very strict nighttime noise regulations at London's Heathrow Airport," Forgeard said at the press conference announcing the A380 launch. As for beating a hasty retreat in an emergency, Airbus says it has that covered too. Mockup tests show its wide doors and exit chutes meet evacuation requirements.

And finally, the A380 will require only minor upgrades to runways and terminals. Although it will be bigger than anything now flying, it can park in a standard slot.



Boeing's Giant: 747X Stretch

An aviation milestone the night it first took to the sky on its first revenue-producing flight, the Boeing 747 jumbo jet has grown—literally—over the past 31 years.

More than 1200 of the classic jumbo jets have been delivered since Pan Am put the Boeing 747-100 into service on its New York to London route on Jan. 21, 1970. "Boeing airplanes changed the world," says Alan Mulally, president of the company's commercial airplanes division. "The 747 is at the heart of this legacy."

Thirty years and 33 billion miles after its first commercial flight, the "queen of the sky" was honored by the U.S. Postal Service as one of America's top three achievements in aviation with its own postage stamp, along with the Wrights' first flight and Lindbergh's Atlantic crossing. "I think that's pretty good company," says Phil Condit, Boeing chairman and chief executive officer. The 747 has even won acclaim from New York's Museum of Modern

Art, which has one on its design collection wish list.

But Boeing isn't resting on its laurels. It has progressively increased both the range and payload of its 747 class. "The 747-400 is an entirely new airplane, with improved aerodynamics, digital avionics, a high-tech flight deck, the latest in-flight entertainment system and 3000 miles more range," says Ray Conner, vice president and general manager of the 747 division.

In recent years, Boeing executives have discussed a larger passenger version, the 747X Stretch. Referred to as the 747X, it would take advantage of the potential to move the top deck bulge that distinguishes the 747 family farther aft, creating room for additional seating.

"While no timetable has been set, the airplanes are beginning to take shape in computer models," says a Boeing executive. As now conceived, the 747X family would use the same engines as the Airbus A380. A modified 747-400 Stretch would be 263 ft. long and be able to fly more than 500 passengers about 9000 miles.

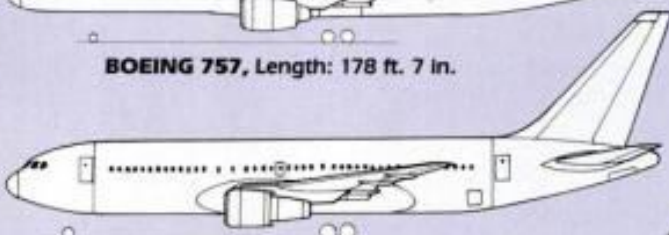
“The A380 has also cleared the three hurdles set up by government regulators: noise, safety and fit.”



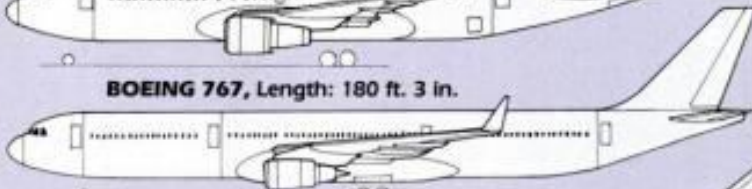
How Big Is Giant?



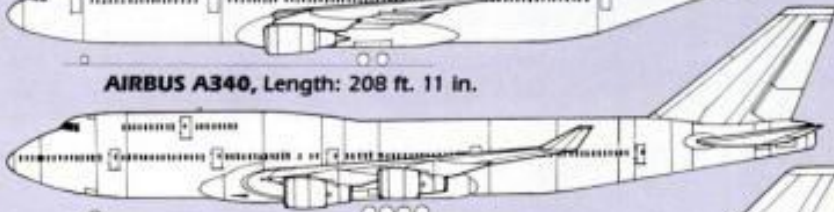
BOEING 757, Length: 178 ft. 7 in.



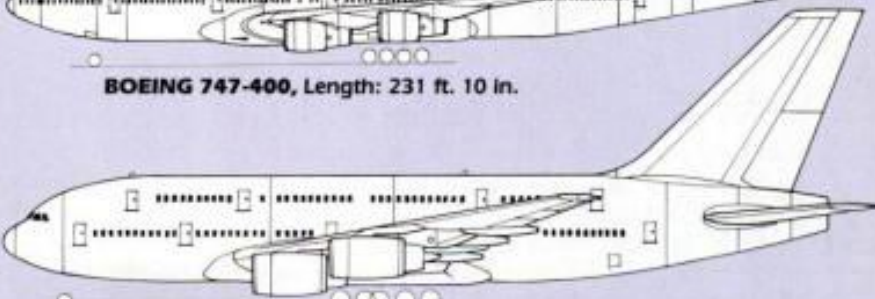
BOEING 767, Length: 180 ft. 3 in.



AIRBUS A340, Length: 208 ft. 11 in.



BOEING 747-400, Length: 231 ft. 10 in.



AIRBUS A380, Length: 239 ft. 6 in.

Building Superjumbos

While airports can handle flying hotels with minimal upset, Airbus will have to make one big change in how it builds planes. The company has a far-flung operation, with factories in Germany, France, the United Kingdom and Spain. Each builds sections of the plane, which are flown to Toulouse, France, for final assembly. A380 subassemblies will be too big to fly. Instead, they will be loaded onto roll-on/roll-off ships at various European ports, and travel to the French harbor at Bordeaux. Here, they will be moved by barge along the Garonne River to Toulouse.

Assembly and production flight tests will be carried out in Toulouse. Then, the planes will take off for Hamburg, Germany, where they will be fitted with cabin furnishings and painted. Customers will pick up their aircraft at either Hamburg or Toulouse. Airbus hopes to eventually turn out four planes per month.

Just-In-Time Delivery

The first superjumbo will arrive just in time. Airline deregulation has decreased the cost of airline tickets and made plane travel more popular

than ever. Airbus estimates that this and other factors will combine to nearly triple air traffic in 20 years. Yet, at the very time air travel has become more popular, airport

construction has virtually ground to a halt in the United States.

This means that the only way airlines will be able to move more passengers between major airports is by moving to still larger planes. The era of the flying hotel is scheduled to take off, right on time.

For Science News And Story Updates

Check the Science channel on the PMZone Web site at popularmechanics.com/science

Science

SONIC CRUISER

A radical new aircraft design skirts the edge of the sound barrier and puts the thrill back in flying.

BY JIM WILSON





■ In a world where progress is defined with the words “bigger” and “faster,” the specs for the Boeing Sonic Cruiser seem downright underwhelming. As currently envisioned, it will carry 225 passengers, about half as many as a Boeing 747, the plane that opened the era of widebody flight in 1969. Nudging the sound barrier at Mach .98, the Sonic Cruiser will move hundreds of miles per hour slower than the British-French Concorde SST, which also has been flying since 1969. Despite these apparent limitations, the new Boeing plane has caused a stir within the aviation industry because it promises, at long

COVER STORY

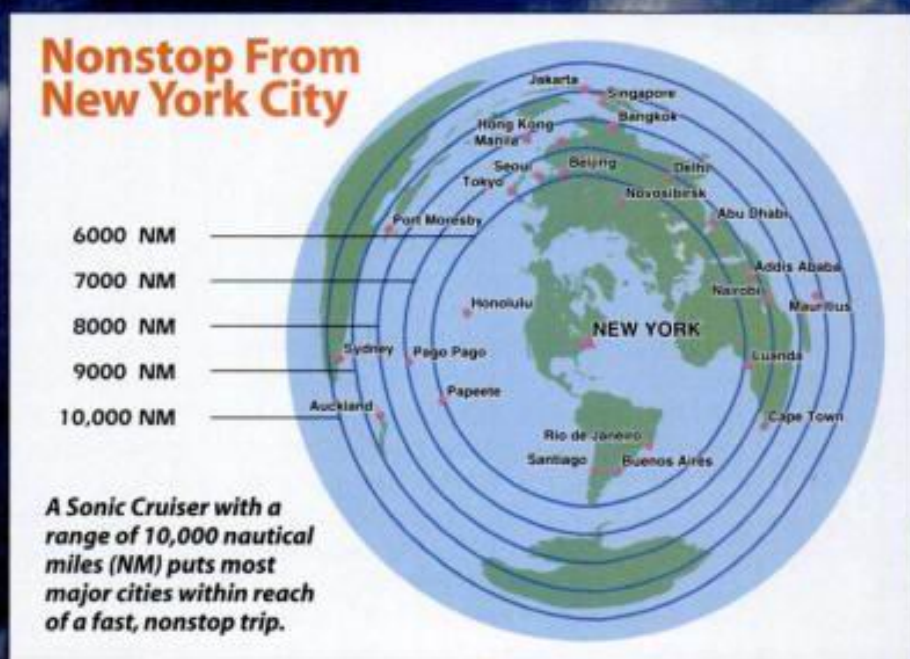
last, to deliver what passengers say they most want from modern jet travel—a faster and more comfortable ride to distant destinations. Take off from New York City after a

late breakfast and arrive in downtown Los Angeles for lunch. The trip is roughly an hour faster than the current ride on conventional airliners, which travel at about Mach .80. Raw speed is only part of the reason for the faster flight. The Sonic Cruiser flies at 45,000 ft. “Flying higher offers a smoother ride and gets you above most traffic,” says Mike Bair, Boeing’s executive vice president for aviation services. Getting to cruising altitude won’t necessarily make the Sonic Cruiser popular with the white-knuckle crowd. After a brisk dash down the runway, it will climb out steep and fast, leveling off at nearly 2 miles higher than other airliners. Landing will begin with a shallow dive instead of a gentle descent. But putting the thrill back in flying is just icing on the cake. The reason for the fast climb and descent is to spend as much time as possible at the more efficient higher altitude.



The secret to the Sonic Cruiser's ability to fly fast—and cheap—is a design tool that, until now, has been chiefly applied to military aircraft. It is called computational fluid dynamics (CFD). Since the time of the Wright brothers, aeronautical engineers have treated air as a fluid. In old-fashioned wind tunnels, smoke was injected to study how air moved around the surfaces of plane wings and fuselages. CFD takes the process digital, creating mathematical models of the aircraft and the airflow that moves around it. This virtual aircraft now can be shaped, flown and reshaped again, without ever leaving the computer. By the time designers build a model for wind-tunnel testing, it is close to aerodynamic perfection.

The use of CFD has enabled Boeing to overcome the greatest single roadblock to building a fast plane that airlines could affordably operate in the transonic region—that is, at



the edge of the sound barrier. Early testing revealed that achieving Sonic Cruiser-like performance was destined to fail because the wing simply produced too much drag as it approached transonic speeds. This re-

quired the planes to burn more fuel, which in turn limited their range and made them too expensive to operate. It is chiefly for this reason that the Concorde failed to ignite the imaginations of airlines beyond

"The use of CFD has enabled Boeing to overcome the greatest single roadblock to building a fast plane."



France and Britain, the countries that sponsored its development.

Using CFD, Boeing was able to make the Sonic Cruiser's airframe exceptionally slick at transonic speeds. Achieving this required an unusual "cranked arrow" wing. It creates so little drag at transonic speed that when two fighter jets were equipped with the design during a military research program, they broke the sound barrier without kicking in their afterburners. "The use of computational fluid dynamics and new materials allows us to do so much more to tailor the new aircraft's aerodynamics," says John Roundhill, vice president of marketing for Boeing.

Boeing has not yet selected an engine, but industry insiders say it is likely to be a variation of the powerplant on its 777 jumbo jet.

The most unique visible feature of the Sonic Cruiser is the way the wing attaches to the point where

the fuselage tapers. Boeing is saying little about its new wing design. However, it appears to draw heavily on research conducted in the 1950s by Richard T. Whitcomb of the NASA Langley Research Center, and makes use of what aeronautical engineers refer to as area-rule technology. According to NASA, this airfoil design has a flattened upper surface that delays the formation of shock waves to a point closer to the trailing edge. Moving the wing rearward makes for a wider passenger cabin. The Sonic Cruiser is envisioned as having eight-across seating with two aisles.

The Boeing illustrations also show a small forward wing. Boeing engineers stress that its plans are highly

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preliminary. The actual plane could carry as few as 100 or as many as 300.

Regardless of its size, the Sonic Cruiser will make extensive use of lightweight composites in place of aluminum. Every pound saved on the airframe is a pound available for fuel. This translates into range, which Boeing sees as the key to making the Sonic Cruiser profitable for airlines. Boeing has set the Sonic Cruiser's base-line range at 8900 nautical miles (NM), nearly 2000 farther than current aircraft. Extended-range versions could fly 10,000 NM. In terms that international flyers understand, the Sonic Cruiser will mean nonstop flying to nearly anywhere on Earth, perhaps as early as 2005.

PM

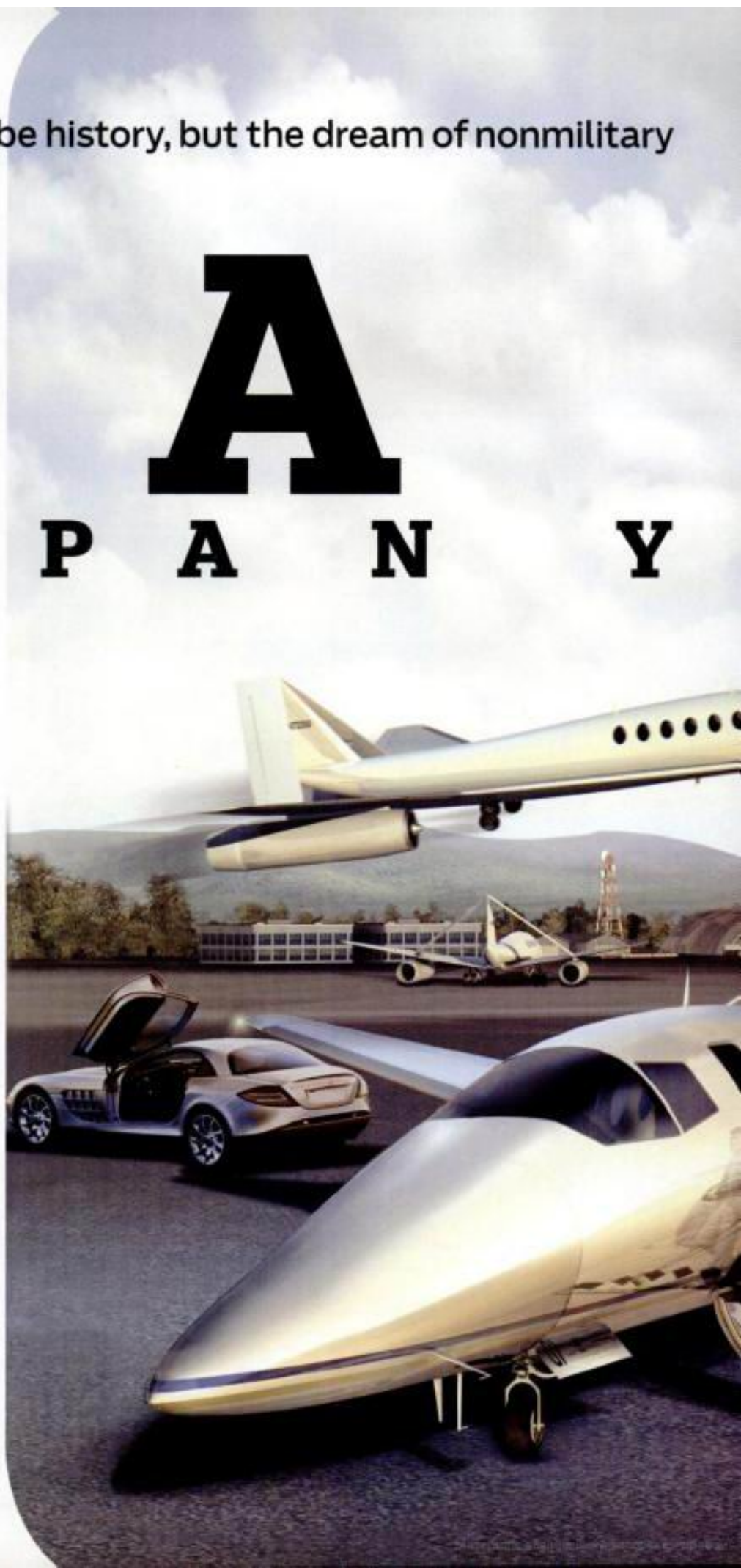
The Concorde may be history, but the dream of nonmilitary

F A C O M P A N Y

BY **MALCOLM V. LOWE**

In the mind's eye, it gleams. It hasn't yet been built, but already the airplane speaks of performance, power and naked privilege like no sports car, penthouse or yacht ever could. The aircraft being devised in the inner sanctum of Lockheed Martin's legendary Skunk Works will be sleek. It will be expensive. Most of all, it will be fast—faster than any private airplane now in existence, faster even than many of the world's military jets. In fact, the new business jet will fly at near-Concorde speeds: It will be the world's first supersonic jet an individual can own.

ILLUSTRATION BY **PAUL DIMARE**



supersonic flight still lives. Meet the supersonic business jet.

S

T



BOOM TIMES: Supersonic business jets like these could be flying as soon as 2010. The inverted "V" attached to the wings and tail is designed to mute the plane's sonic boom.

LEGALLY BREAKING THE SOUND BARRIER

A federal law prohibiting sonic booms over the continental United States killed the American Supersonic Transport (SST) in the 1970s and discouraged work on a supersonic business jet (SBJ). In May, Lockheed Martin engineer John M. Morgenstern won a patent for a low sonic boom aircraft design.

MASTER ARTIST

John Batchelor painstakingly derived this design by studying recent SBJ patents. Such work—created not on a computer but by pen and brush—has earned the artist a worldwide reputation. Among his many projects for PM have been cutaways of the F-22 Raptor and F-35 Joint Strike Fighter.

1 SOFTENING A SONIC BOOM:
A TAIL LEADING UP TO AN INVERTED "V" SHAPE BRACES THE SWEEPED ARROW-SHAPED WINGS TO THE REAR FUSELAGE VIA THE VERTICAL TAIL. STRUCTURALLY, THIS INVERTED "V" TAIL STIFFENS THE WING. BUT CONTRARY TO APPEARANCES IT HAS LITTLE TO DO WITH LIFT. RATHER, IT IS MAINLY INTENDED TO CREATE A MODIFIED PRESSURE WAVE THAT "SOFTENS" THE SONIC BOOM.

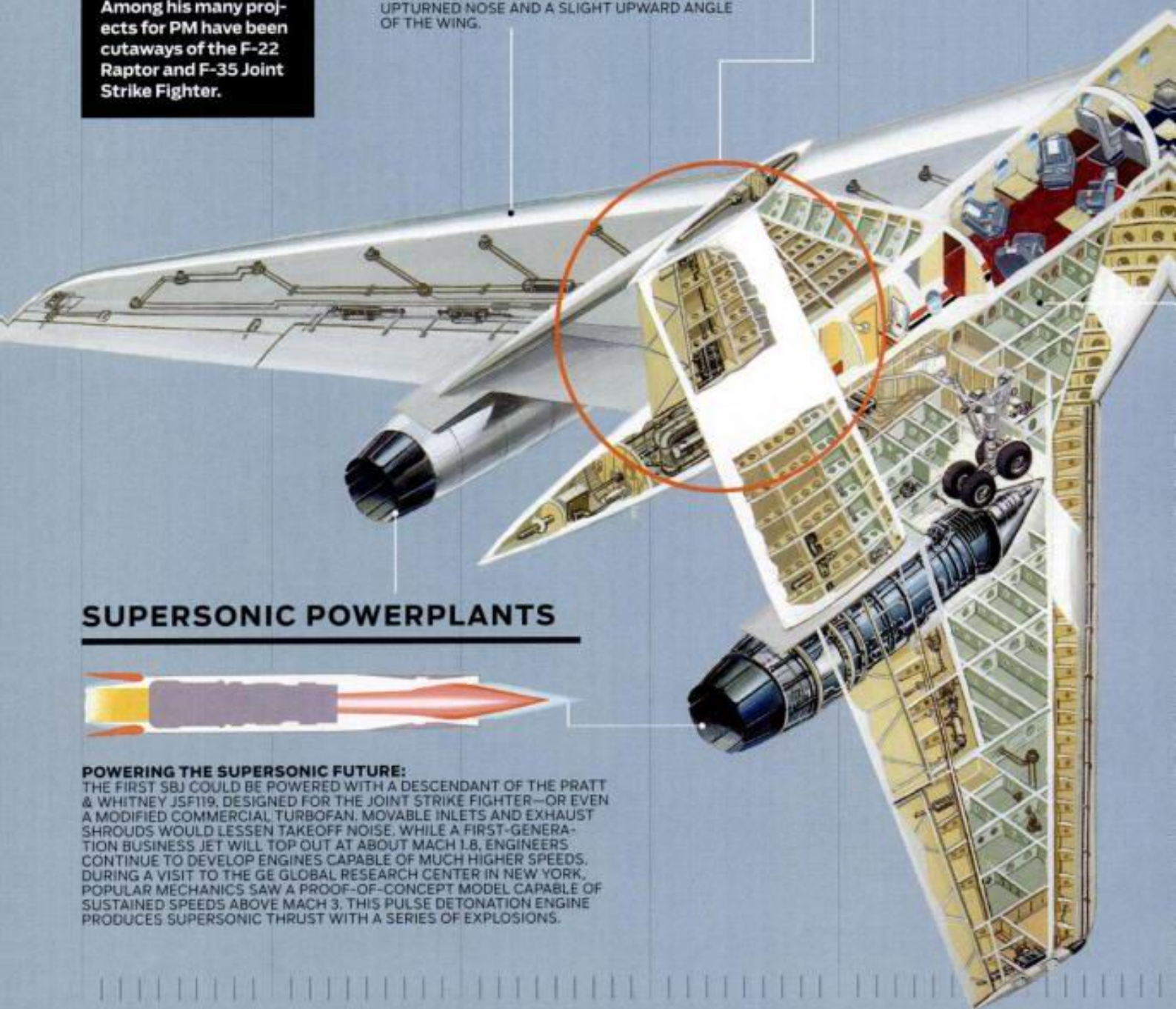
2 FORM FOLLOWS FUNCTION:
THE DISTINCTIVE SHAPE OF THE SBJ DERIVES FROM THE NEED TO WEAKEN THE PRESSURE WAVE THAT FORMS AS THE AIRCRAFT ENTERS SUPERSONIC FLIGHT. THIS IS ACCOMPLISHED WITH AN UPTURNED NOSE AND A SLIGHT UPWARD ANGLE OF THE WING.

SUPERSONIC POWERPLANTS



POWERING THE SUPERSONIC FUTURE:

THE FIRST SBJ COULD BE POWERED WITH A DESCENDANT OF THE PRATT & WHITNEY JSF119, DESIGNED FOR THE JOINT STRIKE FIGHTER—OR EVEN A MODIFIED COMMERCIAL TURBOFAN. MOVABLE INLETS AND EXHAUST SHROUDS WOULD LESSEN TAKEOFF NOISE. WHILE A FIRST-GENERATION BUSINESS JET WILL TOP OUT AT ABOUT MACH 1.8, ENGINEERS CONTINUE TO DEVELOP ENGINES CAPABLE OF MUCH HIGHER SPEEDS. DURING A VISIT TO THE GE GLOBAL RESEARCH CENTER IN NEW YORK, POPULAR MECHANICS SAW A PROOF-OF-CONCEPT MODEL CAPABLE OF SUSTAINED SPEEDS ABOVE MACH 3. THIS PULSE DETONATION ENGINE PRODUCES SUPERSONIC THRUST WITH A SERIES OF EXPLOSIONS.



3 FLY-BY-COMPUTER CONTROL: LIKE THE F-22 JET FIGHTER, THE SBJ FEATURES A SO-CALLED GLASS COCKPIT. COMPUTERS MAKE SECOND-BY-SECOND ENGINE AND CONTROL SURFACE ADJUSTMENTS.



4 BLUNTING THE BOOM: MORGENSTERN'S EARLY PATENTS SHOW A SMALL RETRACTABLE CANARD, WHICH HE CLAIMS BLUNTS THE SONIC BOOM BY WIDENING THE FRONT OF THE PLANE. IT ALSO PROVIDES ADDITIONAL LIFT. THIS IS NEEDED BECAUSE A WING OPTIMIZED FOR SLICING THROUGH THE AIR AT SUPERSONIC SPEEDS PROVIDES TOO LITTLE LIFT AT THE LOW SPEEDS ENCOUNTERED DURING LANDINGS.

5 FUEL FOR LONG HAULS: THE LONGER THE TRIP, THE MORE ATTRACTIVE SUPERSONIC FLIGHT BECOMES. TO FEED ITS ENGINE, THE SBJ WOULD STORE FUEL IN WINGTANKS, SHOWN IN GREEN.

6 SBJ SPECIFICATIONS:

- **WINGSPAN:** 55 FT.
- **LENGTH:** 130 FT.
- **TAKEOFF WEIGHT:** 140,000 POUNDS
- **STRUCTURE:** ADVANCED COMPOSITES
- **PRICE:** \$100 MILLION

It will help to be a rich individual. The estimated asking price for the supersonic business jet (SBJ) is \$100 million. The delivery date is still uncertain, since the Skunk Works has wrapped the SBJ in the secrecy that's a hallmark of its Palmdale, Calif., headquarters. "All that we are saying is that we are exploring supersonic suppression technology that can be applied to either government or commercial contracts," says Skunk Works spokesperson Dianne Knippel. "If you're asking, 'Are you specifically working with a commercial customer for a business jet?'—I can't answer that."

Others in the aviation industry have been more forthcoming about their own supersonic projects. "We have the technology to produce a supersonic business jet—now we need to demonstrate it," says Harvey Maclin, manager for Advanced Technology, Marketing and Government Programs for General Electric Transportation and Advanced Engineering in Cincinnati. A number of industry sources have confirmed a hush-hush plan to build at least one test plane in an effort called the Super 10 Initiative. GE, NASA and all the major powerplant and airframe manufacturers—including Lockheed Martin—are involved. Though it meets weekly, until now the group has operated outside the public eye. The Initiative will send detailed proposals to NASA early next year with the hope of securing additional funding and support for an experimental test plane, the Super Sonic Cruise Technology Demonstrator.

While supersonic-capable warplanes have been built for decades, such travel for civilians has been limited to the Concorde, which was retired late last year. There are no planes to take its place. A 1968 law forbidding the creation of nonmilitary sonic booms over the United States prevented the American Supersonic Transport (SST) from ever getting off the ground. The crash of the Soviet Union's TU-144 at the 1973 Paris Airshow hastened the cancellation of the program in 1978. During the 1990s, American business jet producer Gulfstream Aerospace, the Russian fighter giant Sukhoi, France's Dassault, and Boeing all flirted with the idea of creating a civilian supersonic jet, but none of the projects came to fruition. Nevertheless, the market exists.

1947



X-1: A NEW ERA

Chuck Yeager opened the era of supersonic flight by proving that flying faster than sound was a solvable engineering problem.

1953



F-100 SUPER SABRE

In the process of building the first production supersonic jet, the aircraft industry learned most of what it would need to know to build a commercial SST.

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SPEED:
Mach 1.8

COST:
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PRIVATE JETS GO

SUPER SONIC

Secret
Skunk Works
Plans
Revealed

SEE PAGE 72



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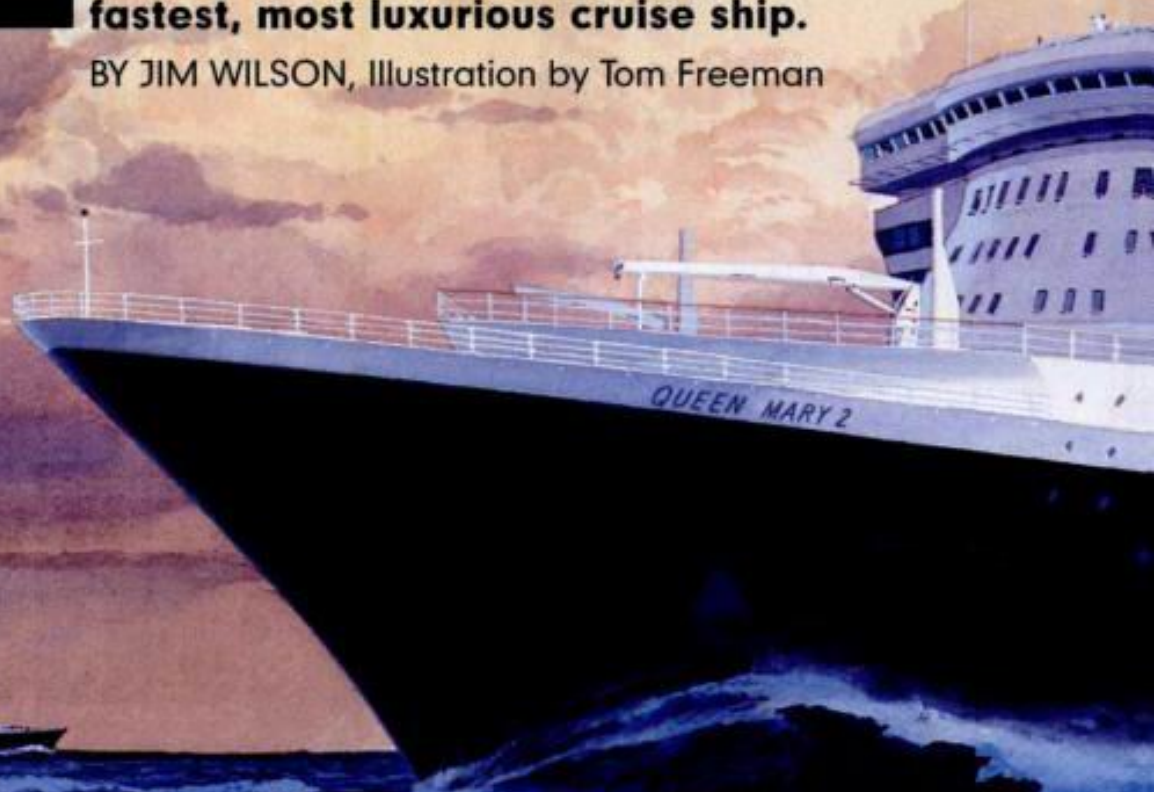


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CROWNING A NEW QUEEN

The *Queen Mary 2* is the biggest, fastest, most luxurious cruise ship.

BY JIM WILSON, Illustration by Tom Freeman



When Britannia ruled the waves, a ticket stamped "POSH" supposedly bought a traveler the height of luxury: a "port out, starboard home" berth on the shady sides of the ship. Today, the password for opulence is QM2, for *Queen Mary 2*. Nearly as long as the Empire State Building is tall, the \$820 million QM2 is the most intense concentration of

NAVAL ARCHITECTURE

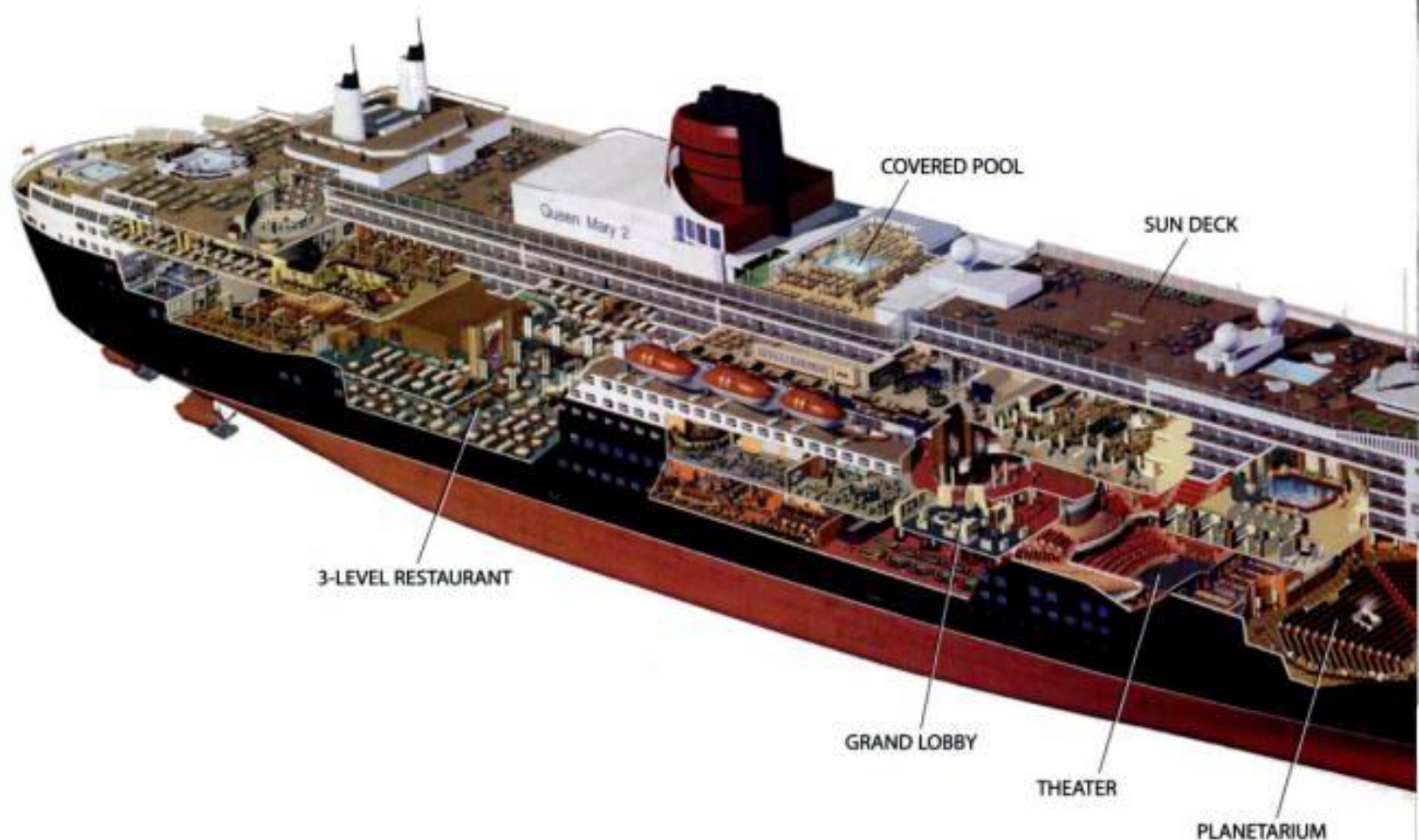
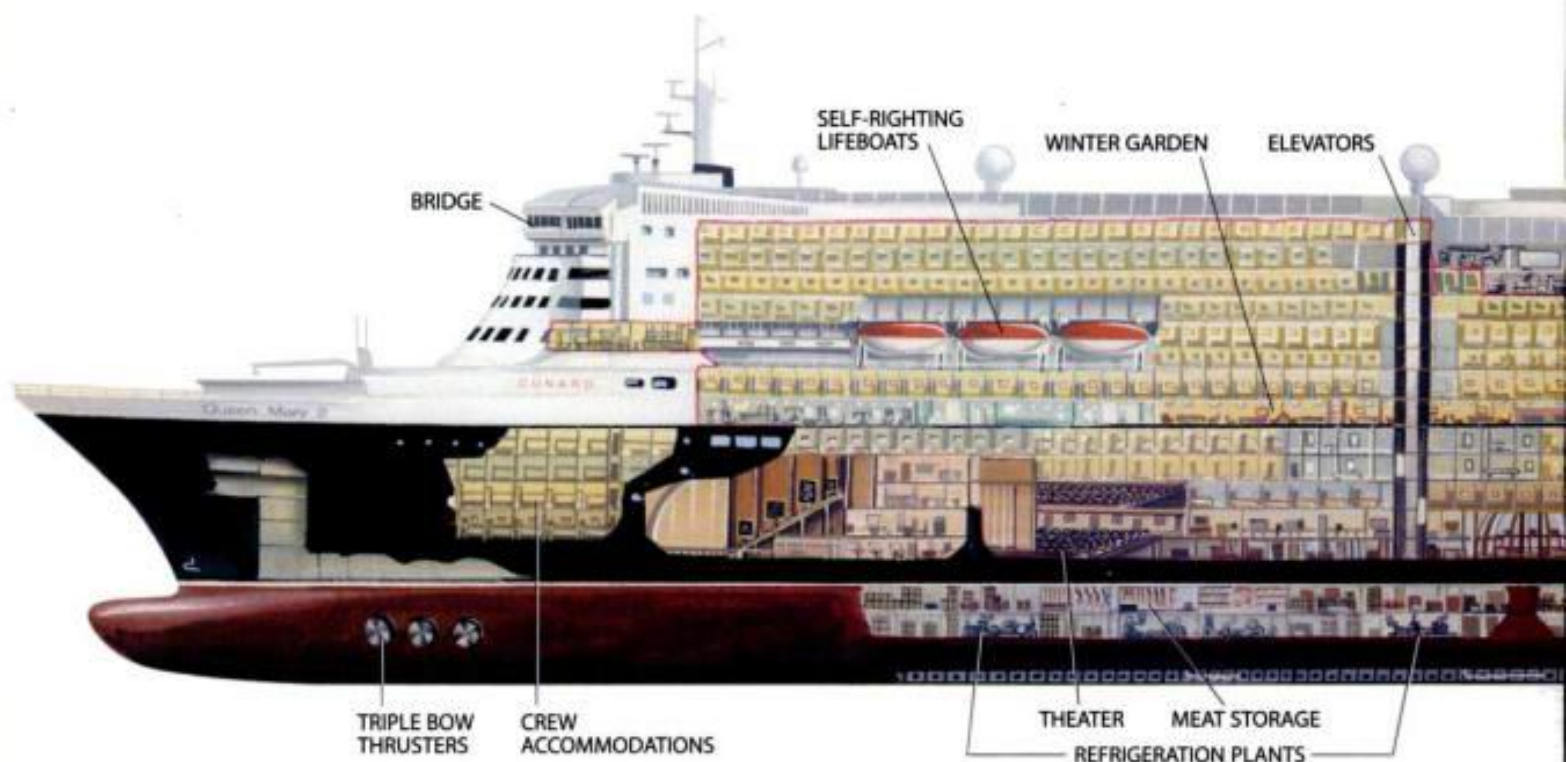
creature comforts on the planet. Dinner in the 1300-seat, 3-tier dining room is served on plates rimmed with gold and platinum. There are so

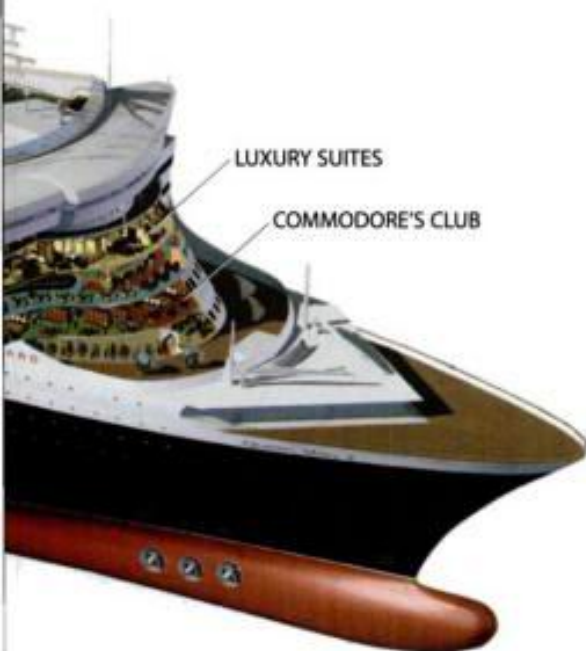
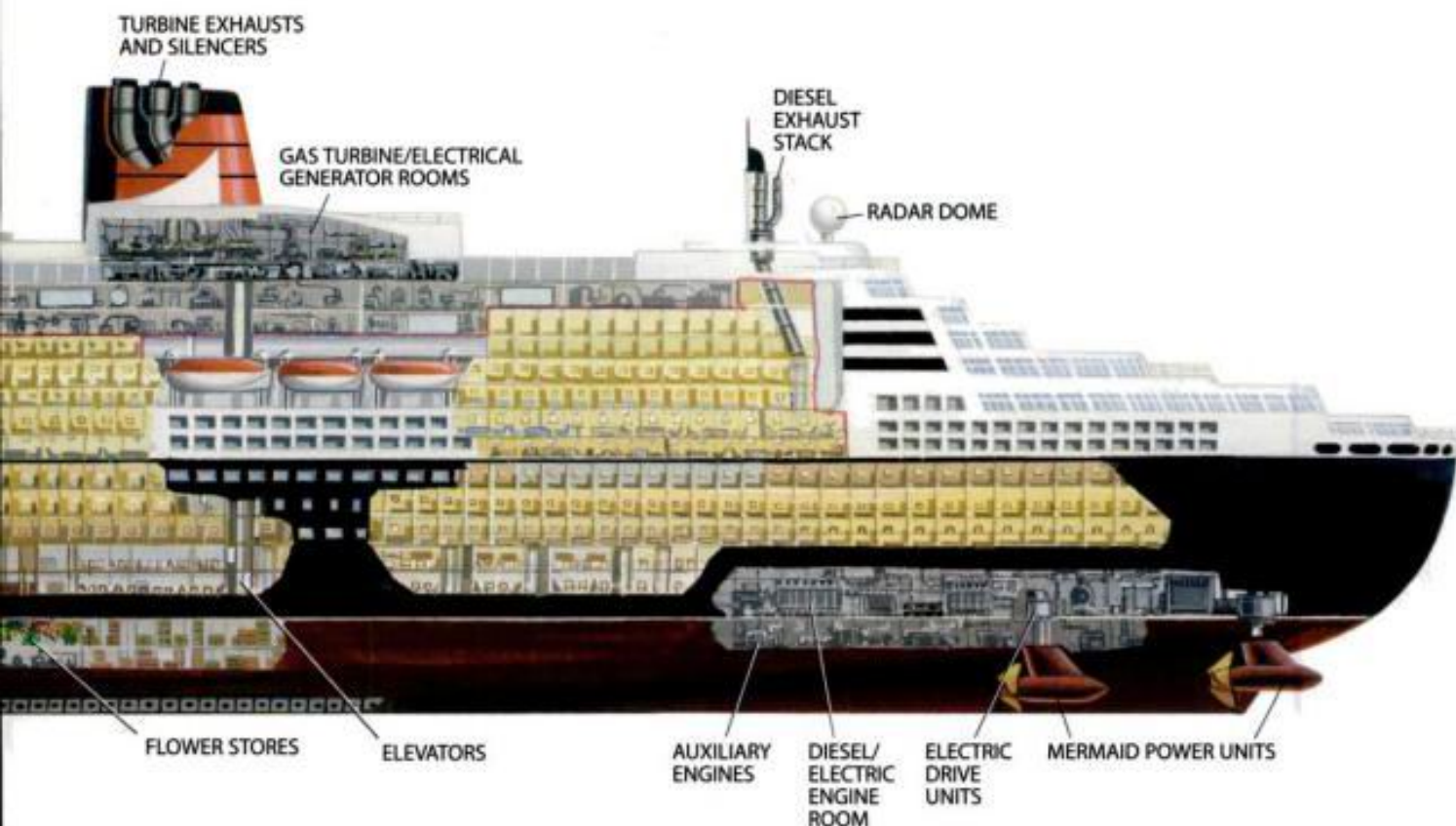
many different types of pillows, the crew includes a pillow concierge whose sole job is to help you choose. Not that you'll want to pass the time away sleeping. For fun, there is a casino, a disco, and a theater with a repertory company trained by London's legendary Royal Academy of Dramatic Art, whose graduates include Sir John Gielgud, Vivien Leigh and Sir Anthony Hopkins. For those who prefer more cerebral pursuits, there is a library and a museum-quality planetarium. Interspersed among the 1310 staterooms are five swimming pools and a 20,000-sq.-ft. spa. There are shops



*The Queen Mary 2 will bring
the golden age of trans-Atlantic
sailing into the 21st century.*

Inside The Queen Mary 2





The Measure Of Royalty

Tonnage	150,000 gross tons
Length	1132 ft.
Beam	135 ft.
(Beam at bridge wings)	147.6 ft.
Draft	32.75 ft.
Height	236.2 ft. (keel to funnel)
Passenger Decks	17
Speed	28.5 knots
Crew	1253

Source: Cunard

Modern shipbuilding technology that replaced the steam engine and the central propeller shaft with diesel/electric generators and Mermaid drives enabled naval architects to devote more space to entertainment areas. The hull design provides a smoother ride in rough North Atlantic waters.

Science

GOING UP

Self-assembling nanotubes bring the impossible dream of space elevators down to Earth.

BY JIM WILSON

Illustrations by Paul DiMare

NOW BOARDING
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Magnetically levitated elevator cars that never touch the tether would cruise at 1200 mph as they carry people and cargo to and from the zero-gravity lab. Energy recovered from cars heading down would help power those going up.

In the not-too-distant future, riding into space in a rocket may seem as impractical as crossing the continent in a Conestoga wagon. Rockets will still be used for the long trips to the outer planets and stars, but for short hops—jobs in zero-gravity laboratories and vacations on the moon—we will simply take the elevator. The first stop will be a massive

COVER STORY

zero-gravity platform. The "roof" will be a captured asteroid that anchors the tower in place. You'll have to hang on tight as you near the end of the ride. If you don't, the same laws of physics that carried David's rock into Goliath's head will propel you as far as Saturn.

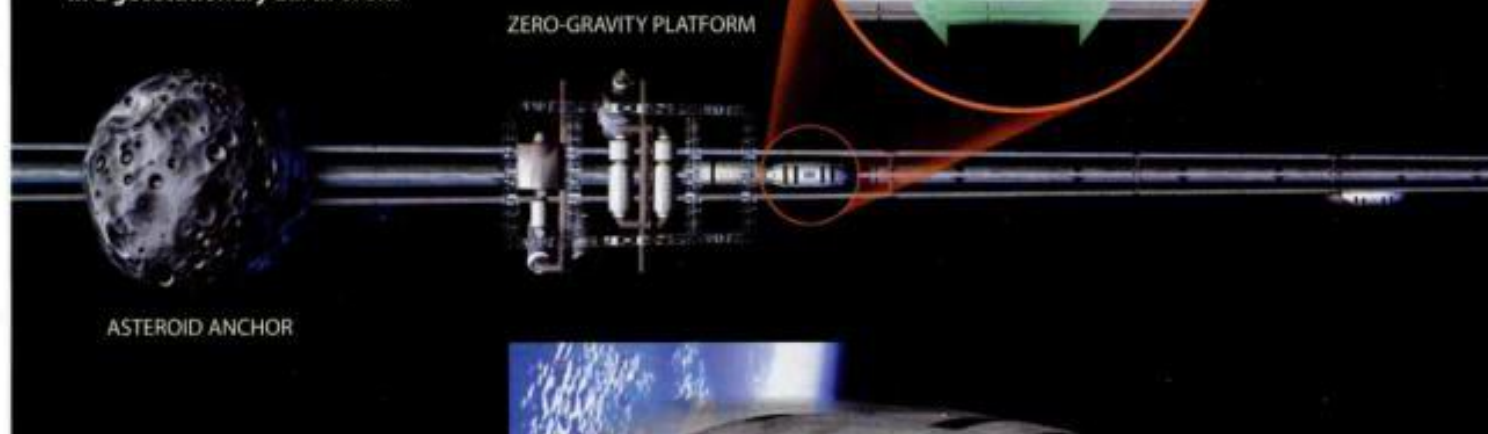
It is a historically apt analogy. "The idea of building a tower into space dates back to some of the earliest known manuscripts," says David Smitherman. NASA's point man for advanced spaceflight concepts, he reminds us that the original space tower, better known as the Tower of Babel, was already an old story when told in the

Bible's book of Genesis. "It has been dreamed, invented and reinvented many times throughout modern civilization." Two decades before Arthur C. Clarke's 1979 novel, *The Fountains Of Paradise*, introduced the space elevator to the English-speaking world, Russian engineer Yuri Artsutanov described it in a Sunday supplement article in the old Soviet newspaper *Pravda*.

The idea remained suspended between science fact and science fiction until three years ago. A group of researchers from several top engineering schools and aerospace companies, along with NASA scientists, met at the Marshall Space Flight Center in Huntsville, Ala., to consider the technological hurdles to building a space elevator. Their conclusion: "In the later part of the 21st century it has the potential to provide mass transportation to space in the same way highways, railroads, powerlines and pipelines provide mass transportation across the Earth's surface." Since that 1999 conference, improvements in materials have occurred with rocket-sled speed. Some readers of this article may live to follow POPULAR MECHANICS's coverage of the elevator's construction and the report on our first ride.

How It Works

An asteroid whose position could be slightly adjusted would anchor the zero-gravity station, which would be in a geostationary Earth orbit.



"Theoretically, you could build a tower to GEO [geostationary Earth orbit] out of bubble gum, but the base would probably cover half the sphere of the Earth," says Smitherman. A practical choice of material for the elevator is a major difficulty because of the immense distances involved—22,236 miles to the zero-gravity platform in GEO, and 29,204 miles to the asteroid that would anchor the entire structure in place. Dani Eder of Boeing did a material comparison for the Huntsville conference and found that a column made of structural steel would collapse under its own weight when it reached a height of about 3 miles. The maximum height climbs to 9 miles for aluminum, 71 miles for a carbon/epoxy composite and about 76 miles for boron/epoxy. More exotic high-strength composite materials can soar higher still, but they all top out a long way from GEO.

One of the fundamental and frustrating problems of designing with high-strength materials is that they are usually stronger in tension than in compression, Smitherman explains. "The strongest tensile material readily available today is Polybenzobisoxazole (PBO) graphite epoxy, a high-strength polyaramid fiber capable of supporting its own length up to 114 miles," he says. "What is



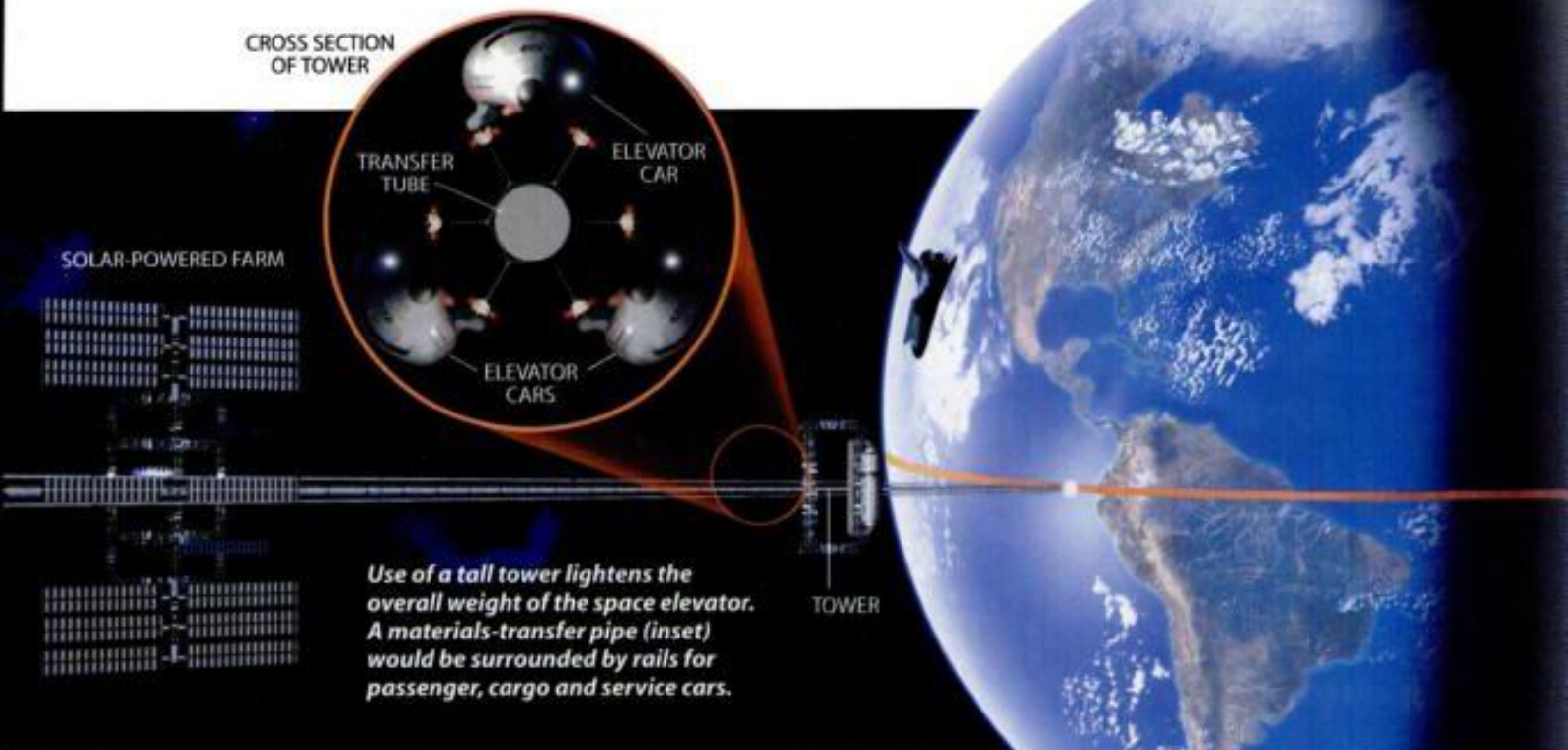
needed is a way to convert tensile strength into compressive strength."

Pressurized Towers

Geoffrey Landis of NASA's Glenn Research Center in Cleveland suggests that one solution would be to pressurize structural members as if they were balloons, thus converting the tower from a compression structure to a tension structure. He calculates that a pressurized structure made of PBO fiber could rise to the astounding height of 1864 miles.

Impressive as this design might seem, a pressurized structure would be subject to the same weakness of all tall towers: buckling. "So, the ideal structure will likely be a combination of a tall tower in compression connected to a tension structure," predicts Smitherman. And this is where science fact dovetails with science fiction.

Futurists and novelists traditionally envision the space elevator as moving along a slender, high-strength tether stretched between the Earth



and an orbiting asteroid. Engineers realize that the tethers would need to taper to support their weight. The filament that would connect to a point on Earth might be so narrow that it could easily slip between your fingers. But, its diameter as it approaches the zero-gravity platform at GEO could measure yards or even miles, depending upon the strength of the material. "Finding the right material in combination with the right construction method is the key to success," says Smitherman.

NASA engineers currently favor a strategy in which the tether connects to the top of a 15-mile-high tower. Nothing even approaching this height has ever been built. Yet, there is confidence that using existing composites and robot-building equipment, constructing a tower of this height is a doable, albeit difficult task. "We came out of the workshop saying, 'We may very well be able to do this,'" Smitherman says.

The Right Material

At the time of the Huntsville conference, the greatest unknown was whether a promising new material made of tubes constructed of sheets of hexagonally arranged carbon atoms would ever be more than a laboratory curiosity. On a weight basis,

these nanotubes would be 100 times stronger than steel. This exceeded by a factor of two the tensile strength NASA estimated would be necessary for the tether. There were, however, problems of scaling up production. Nanotubes had been produced only under carefully controlled laboratory conditions, and had been grown to the length of just a few molecules. And, no one was certain individual tubes could be connected. Since then, nanotechnology researchers at Harvard, Purdue and Rice universities, to name a few, have found ways of not only making nanotubes in large quantities, but of teaching them to "self-assemble" into larger structures. What is more, they have found that it might not be necessary to "grow" a continuous tether. Instead, they may be able to place short segments of high-strength nanotubes in a matrix of high-purity fiberglass.

While answers to questions about materials and construction methods are years from being resolved, Rob Suggs, another NASA researcher in Huntsville, has located possible building sites. The two current frontrunners are the Indian Ocean island of

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Gan in the Maldives chain southwest of India, and the Galápagos Islands in the Pacific. Both locations offer stable geology, mild winds, and calm, hurricane-free, weather.

The surrounding ocean also offers a "safety" feature. Although the tether would have sufficient flexibility to be moved out of the path of meteoroids and space debris, a catastrophic failure would result in gravity causing everything below a 15,534 mile orbital altitude to crash back to Earth.

NASA is working out preliminary plans for a simplified startup system, literally a string hanging from the sky. In his 2002 Presidential Budget Request, President Bush approved \$11 million for perfecting manufacturing techniques for single-walled carbon nanotubes.

Critics, including many at NASA, caution that future propulsion technologies might render the elevator obsolete before it is complete. Yet, the enthusiasts remain undeterred.

"It is indeed very complex," says Smitherman, "but it is less massive than the Great Pyramids of Giza and short in comparison to our interstate highway system."

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Makes Rockets
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RUSSIA'S RADICAL NEW SUPER FIGHTER

The Deadly S-37 Is Set To
Take On America's F-22
Air Superiority Fighter

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RUSSIA'S RADICAL NEW FIGHTER

Russia's fabled Sukhoi Design Bureau builds the S-37, a 21st century fighter to go head-to-head with the F-22.

BY MALCOLM V. LOWE, Photo by Katsuhiko Tokunaga/DACT

► A bold, new combat

aircraft designed by the legendary Sukhoi Design Bureau and now undergoing tests in Russia has taken aim at America's next-generation fighter, the F-22. The Russian challenge comes in the form of the single-seat Sukhoi S-37, the world's first combat aircraft to successfully exploit forward-swept wing (FSW) technology.

First word of the S-37 leaked to the West in 1997, and took Western defense analysts by surprise. Now, after

COVER STORY

more than 120 test flights at the secret Zhukovsky Flight Test Center near Moscow, it is clear that there is nothing like this bird flying anywhere in the world today. Its creator, the Sukhoi group, is considered to be Russia's premier combat aircraft producer. Sukhoi currently produces a family of topnotch operational fighters and fighter-bombers all based on the very agile and powerful

Su-27 air superiority fighter. These include such models as the Su-33 aircraft carrier-based air defense fighter and the thrust-vectoring Su-37, a fighter and ground-attack aircraft. The general director of the Sukhoi Design Bureau and the Sukhoi Aviation Military-Industrial Complex, Mikhail Pogosyan, is proud of his company's success. But looking to the future, he sees the need to build a fifth-generation fighter and to find an eventual replacement for the Su-27. "The S-37 program [has] a critical importance for the development of our company," he tells POPULAR MECHANICS.

Named Berkut, which translates to mean Golden Eagle or Royal Eagle, the S-37 bears an "S" rather than an "Su" designation because it is an experimental rather than production aircraft. Design of the aircraft, originally known as the S-32, began around 1983, and drew on many years of FSW research that had commenced in the former Soviet Union during the 1940s—initially using captured Nazi technology. The Russians

Inside A Combat-Ready S-37



were also well aware of the Grumman X-29 FSW research aircraft, as two of these single-seat, single-engine planes were being tested in America between 1984 and the early 1990s (see "The Outer Limits," Sept. 1996, page 48).

The S-37, however, is almost twice the size of the X-29, with a markedly different configuration. It has a length of 74 ft. and a wingspan of 54 ft. 10 in., with a maximum takeoff weight of just under 75,000 pounds. Power comes from two Aviadvigatel (Perm) D-30F6 turbofans, each developing 34,177 pounds of static thrust with afterburners—but without a thrust-vector ring. Together the engines give the S-37 a respectable, if unspectacular, top speed of around Mach 1.6. The aircraft may be re-engined with Sukhoi's preferred option of two Lyulka (Saturn) AL-41F turbofans with thrust vectoring, when these formidable en-

gines—which pour out 39,350 pounds of static thrust with afterburners—become available.

Unconventional Design

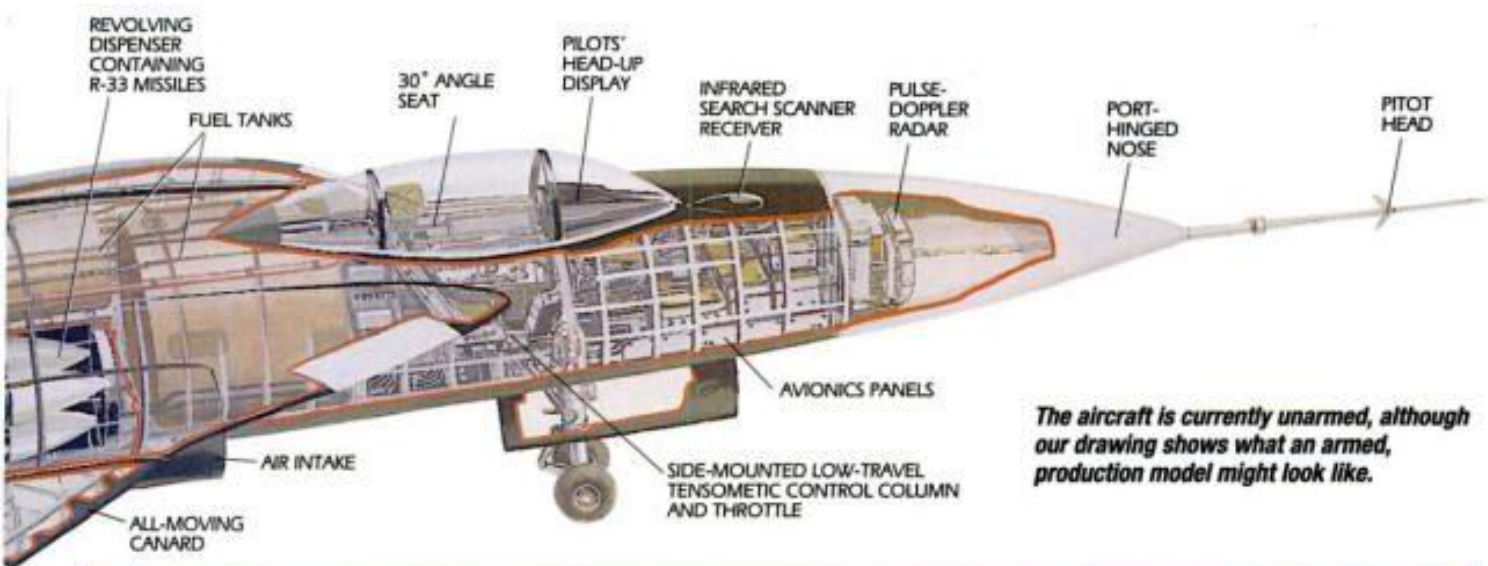
The real innovations in the S-37 lie within its unconventional design. The swept-forward wing is part of a so-called "tandem triplane" arrangement, blending all-moving forward canards with the swept-forward wing, a short-span broad-chord swept horizontal tail plus outward-canted vertical tailplanes. To speed up manufacturing, some parts of the S-37 were borrowed from the Su-27 series, including the undercarriage and vertical tails, but the main flying surfaces are all new. The S-37's FSW layout meets Sukhoi's desire to create a fighter with super-maneuverability—one capable of maintaining stability and control at almost any altitude and angle of attack. Critical to achieving this is the aircraft's computerized fly-by-wire control

system, probably similar to that used in the Su-35 and Su-37, which allows for the basically unstable aerodynamics of the aircraft to be under control at all times. Vital in dog-fights, this system, coupled with the FSW layout, helps the S-37 reach the optimum attitude for launching missiles at short- and medium-range opponents. Pogosyan, formerly the chief designer of the S-37, points out that agility was a top priority. "We were looking for the technical solutions to increase aircraft maneuverability in close combat."

The S-37's forward-swept, slightly tapered wing has leading-edge flaps and trailing-edge flaps and ailerons. Compared to a normal swept-back wing, the FSW potentially has better lift, good antispin and stall resistance, and allows a shorter takeoff run. At transonic speeds (around Mach 0.8 to Mach 1.3), it has a better lift-to-drag ratio than a conventional wing. During

ILLUSTRATION BY JOHN BACHELOR

"A production model of the S-37 would be a match for any Western fighter."



flight, airflow is directed inward across the wing's section, thus preventing aileron and tip stall at higher angles of attack, and allowing better control response at high angles of attack. That's great for dog-fighting. The key to all this is the use of up to 90 percent composite materials in the wing's structure. Sukhoi has made a major breakthrough in the use of advanced composites in the S-37's wing, and these have proven able to cope with the considerable bending and structural loading on this type of wing during close-in maneuvering across a wide speed range.

The FSW concept is very different from plans we've seen for the stealthy F-22 Raptor, its potential American rival (see "21st Century Fighter," Dec. 1999, page 84). Although the S-37 does have some stealth design features, and may be covered with radar-absorbent coatings, low

detectability is secondary to the maneuverability created by the FSW.

Secret Flight Tests

The S-37 first flew in September 1997 at the Russian experimental base at Zhukovsky near Moscow. Test flights have been successful so far, with Sukhoi claiming that the S-37 has made more than 120 flights. But many questions remain.

Will it remain simply as a proof-of-concept aircraft, with no actual production S-37 ever made? Will its radical technology be used in forthcoming Russian fighter designs, perhaps to meet the Russian air force's future heavy fighter requirements? Or will it form the basis of the already-rumored S-54 light fighter, a possible Russian rival to America's Joint Strike Fighter? It can

certainly be said that a production model of the S-37 would be a match for any Western fighter.

The S-37's big rival in Russia is the MiG 1.44. This experimental twin-engined fighter first flew, after many lengthy delays, in February 2000. Most Western observers believe that the MiG design, and not the S-37, will ultimately lead to a production fighter. However, Sukhoi has a possible trump card. The new Russian president, Vladimir Putin, is particularly friendly toward Sukhoi, and his planned reforms of Russia's aircraft industry could benefit Sukhoi. Pogosyan tells PM he is upbeat: "We have a good design and scientific organization, which enables us to successfully compete with the West."

Much of the S-37 program remains veiled in secrecy, but its potentially world-beating design truly extends the boundaries of state-of-the-art fighter technology.

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Science

TWO HOURS

After decades of false starts, scramjets fly off the drawing board and the "Orient Express" lives.

BY JIM WILSON. Illustration by Mark McCandlish



TO TOKYO



Frankly, the Hyper-X is not much to look at. If you saw it on a highway, you might mistake it for a stack of surfboards that had fallen off a truck and been flattened by the passing traffic. But

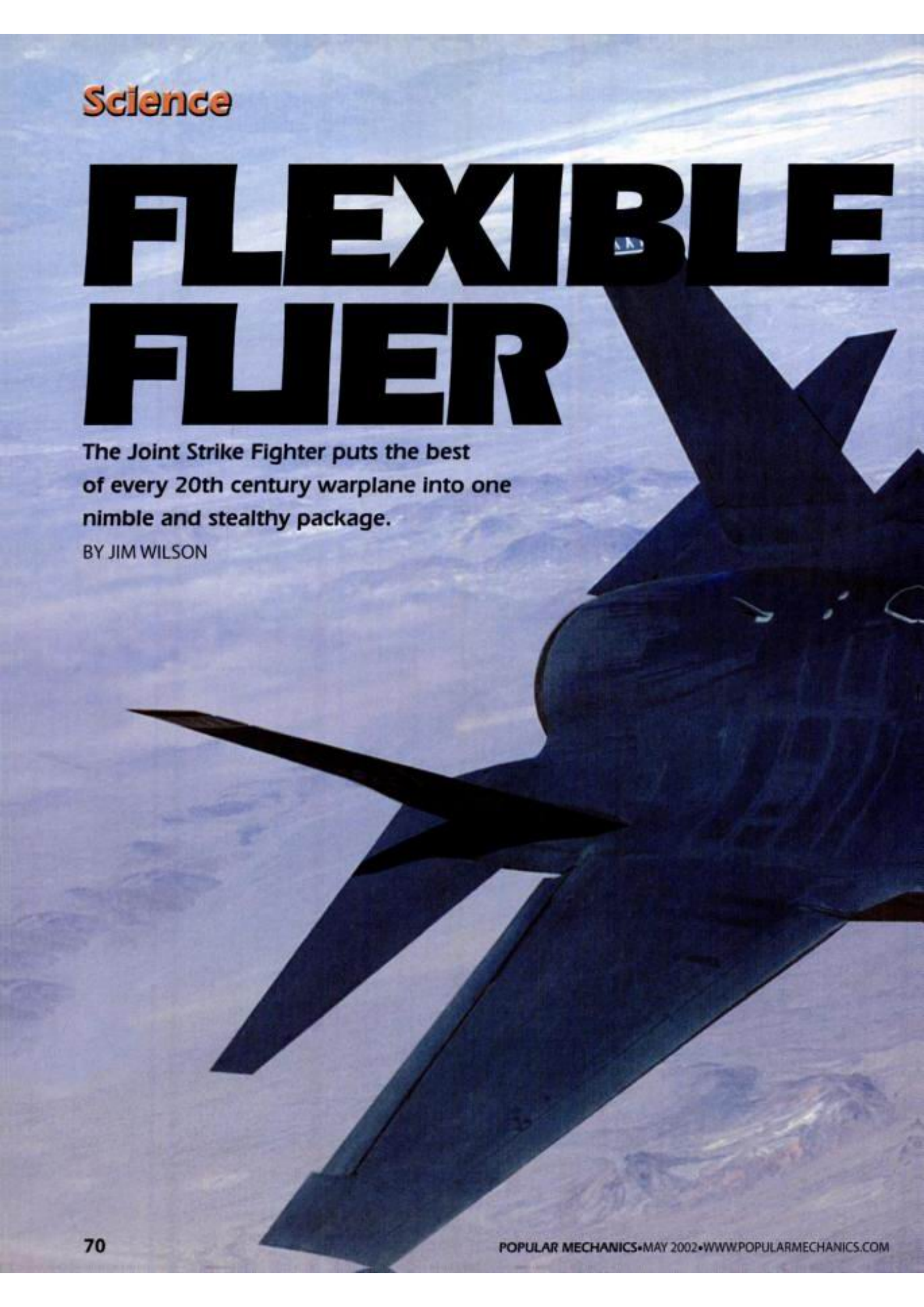
COVER STORY

an aircraft it is, and one with a remarkable pedigree and a promising future. Designated the X-43, the Hyper-X is heir apparent to the SR-71, the world's fastest airplane. About the time this issue of **POPULAR MECHANICS** hits newsstands, a mission controller aboard a specially modified B-52 bomber will drop the X-43 into the sky about 20,000 ft. above the Pacific Ocean. It will be the first of a series of test flights for three identical and expendable Hyper-X aircraft. Seconds after the craft drops away

from its ride, the modified Pegasus rocket mated to the back of the X-43 will ignite, shooting the aircraft to 95,000 ft. When the booster separates, the Hyper-X's exotic scramjet engine will kick in. And, if the data derived from years of careful design studies and countless hours spent in wind tunnels is correct, the Hyper-X will fly faster and faster until, at the conclusion of its third test flight, it reaches Mach 10 and becomes the fastest airplane in the sky.

Theory To Practice

The commercial aviation industry is watching these tests carefully. After decades of false starts and disappointments, the Hyper-X may at last demonstrate that flying at Mach 10 is practical as well as theoretically possible. The X-43 is only a fraction of the size of an airliner but basic operating principles remain the same regardless of size. Success will represent the long-awaited first step toward actually building the Orient Express. Proposed by President Ronald Reagan in his 1986 State of the Union address,



Science

FLEXIBLE FLIER

The Joint Strike Fighter puts the best of every 20th century warplane into one nimble and stealthy package.

BY JIM WILSON



■ The planes that won the Cold War are getting old. They pack as lethal a punch as ever, but like the baby boomer generation they protected, they are beginning to show their age. The electrical system of the Air Force's A-10 Thunderbolt, better known as the Warthog because of its

COVER STORY

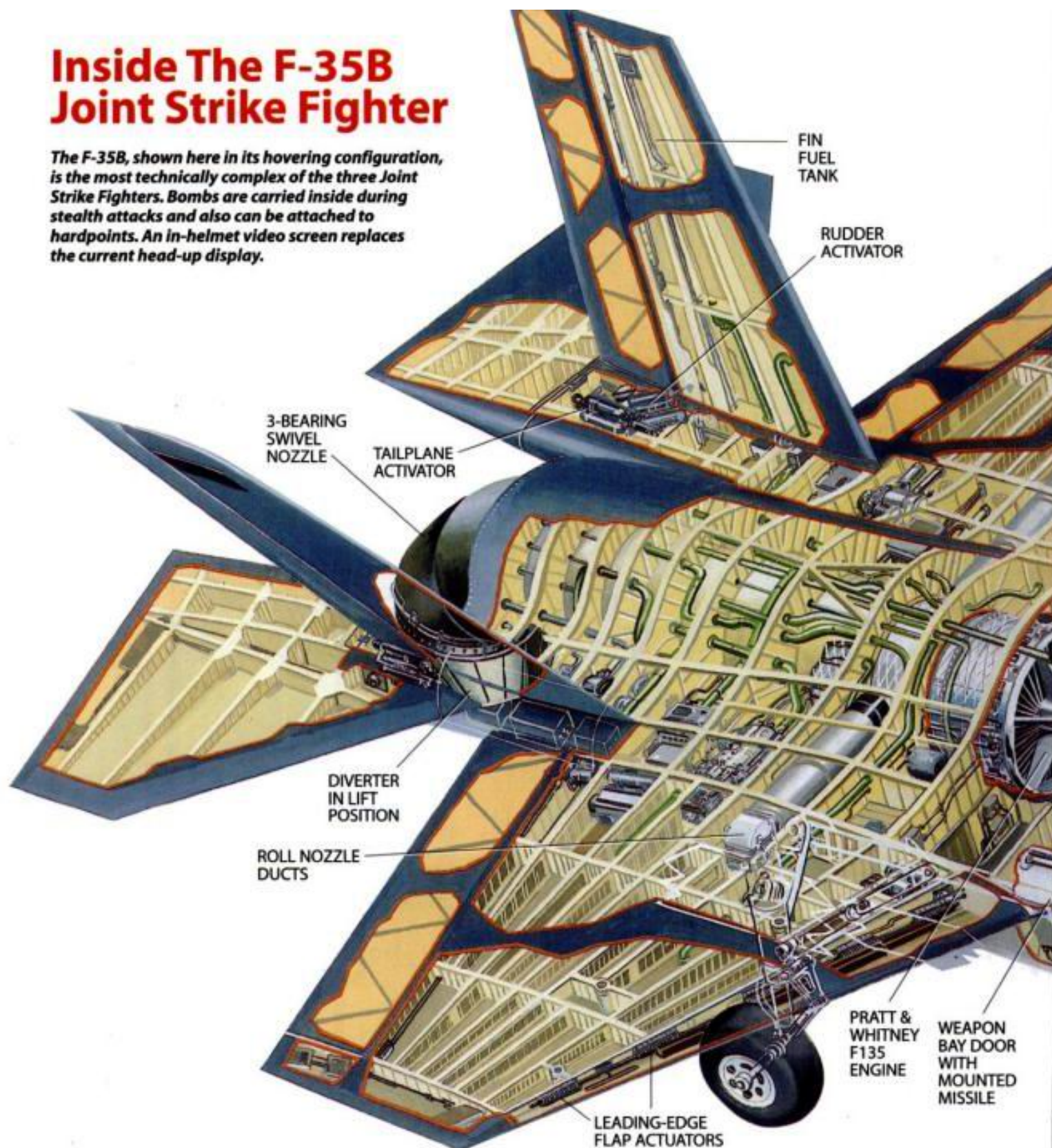
ungainly tail-engine configuration, lacks the juice to handle modern radar and battle-management computers. Salty sea air has hastened the breakdown of the insulation in some Navy jets, causing scores of fires and prompting a program to install arc-fault circuit breakers. The Marines are seriously worried that they could run out of Harrier jump jets.

There is no argument within the defense community that America needs a new family of military aircraft. The problem is money. Keeping one step ahead of the former Soviet Union has driven the cost of aircraft to astounding heights. The U.S. Air Force says that the "fly-away" cost of the first 10 F-22 Raptors, the last fighters designed to counter the Soviet threat, is \$99.7 million each. When the U.S.S.R. folded its tent, the Pentagon decided it was time not only for new planes, but also for a less costly way of doing business. Thus, the birth of America's newest combat aircraft, the F-35 Joint Strike Fighter (JSF).

The F-35s are a family of three aircraft, designated the F-35A, F-35B and F-35C. Similar in shape and size, and

Inside The F-35B Joint Strike Fighter

The F-35B, shown here in its hovering configuration, is the most technically complex of the three Joint Strike Fighters. Bombs are carried inside during stealth attacks and also can be attached to hardpoints. An in-helmet video screen replaces the current head-up display.



powered by the same basic engine, the F-35s will share between 70 and 90 percent of their parts. Yet, under the skin they are three distinctly different machines.

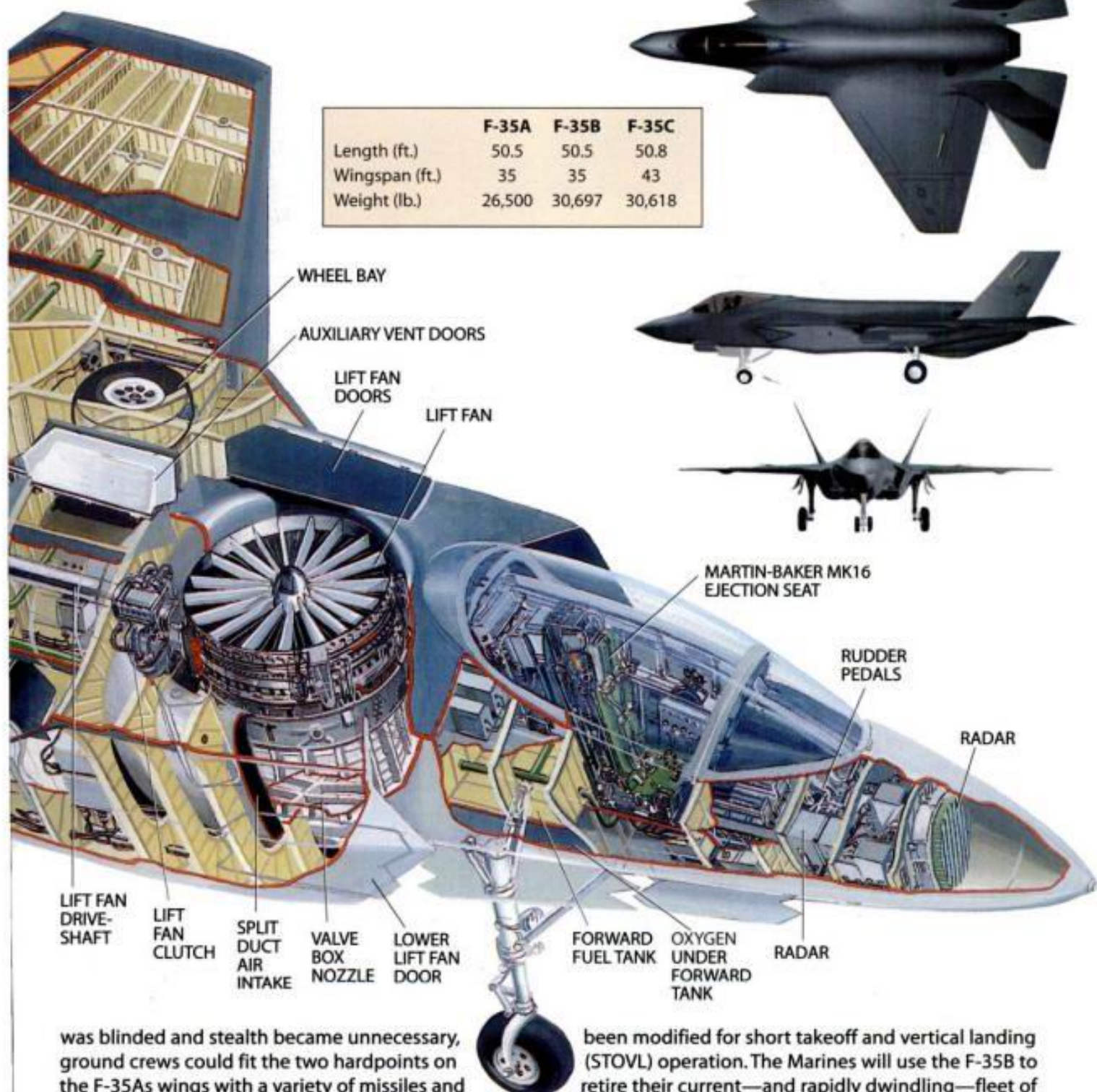
The U.S. Air Force will fly the F-35A. Designed to take off and land from conventional runways, it bears a close family resemblance to the F-22 Raptor air superiority fighter—a trait shared by all three JSF variants. The Air Force wants to use the F-35A to replace its obsolete fleet of A-10 tank killers and rapidly aging F-16 fighters. "The [F-35A] would allow for migration by U.S. forces to an

almost all-stealth fighter force by 2025," says Edward Aldridge, undersecretary of Defense for Acquisitions.

In a future war, F-22s and F-35As would fly complementary missions. The F-22 would establish and maintain air superiority, while the F-35As would attack the enemy on the ground. Planners envision that during the first hours of a war F-35As would take advantage of their near Mach 2 speed and stealth to deliver a pair of internally carried 2000-pound "supersmart" bombs against command and control targets. Once the enemy

"Lockheed Martin's design represents a blend of old and bold technologies."

	F-35A	F-35B	F-35C
Length (ft.)	50.5	50.5	50.8
Wingspan (ft.)	35	35	43
Weight (lb.)	26,500	30,697	30,618



was blinded and stealth became unnecessary, ground crews could fit the two hardpoints on the F-35As wings with a variety of missiles and bombs. If the Air Force holds to its current plans, it will buy 1763 F-35As. The least complicated of the designs, they will cost more than \$30 million each.

U.S. Marines will fly the F-35B, which is detailed in the cutaway drawing above. While its overall shape, size and radar-absorbing stealth coatings are identical to the Air Force F-35A, the powerplant and airframe have

been modified for short takeoff and vertical landing (STOVL) operation. The Marines will use the F-35B to retire their current—and rapidly dwindling—fleet of British-designed AV-8B Harrier jump jets. F-35Bs would be deployed with Marine Expeditionary Units and operate off short-runway landing ships. Eventually, the Marines hope to buy 609 F-35Bs to replace the Harriers, as well as their carrier-based F/A-18C/D Hornets.

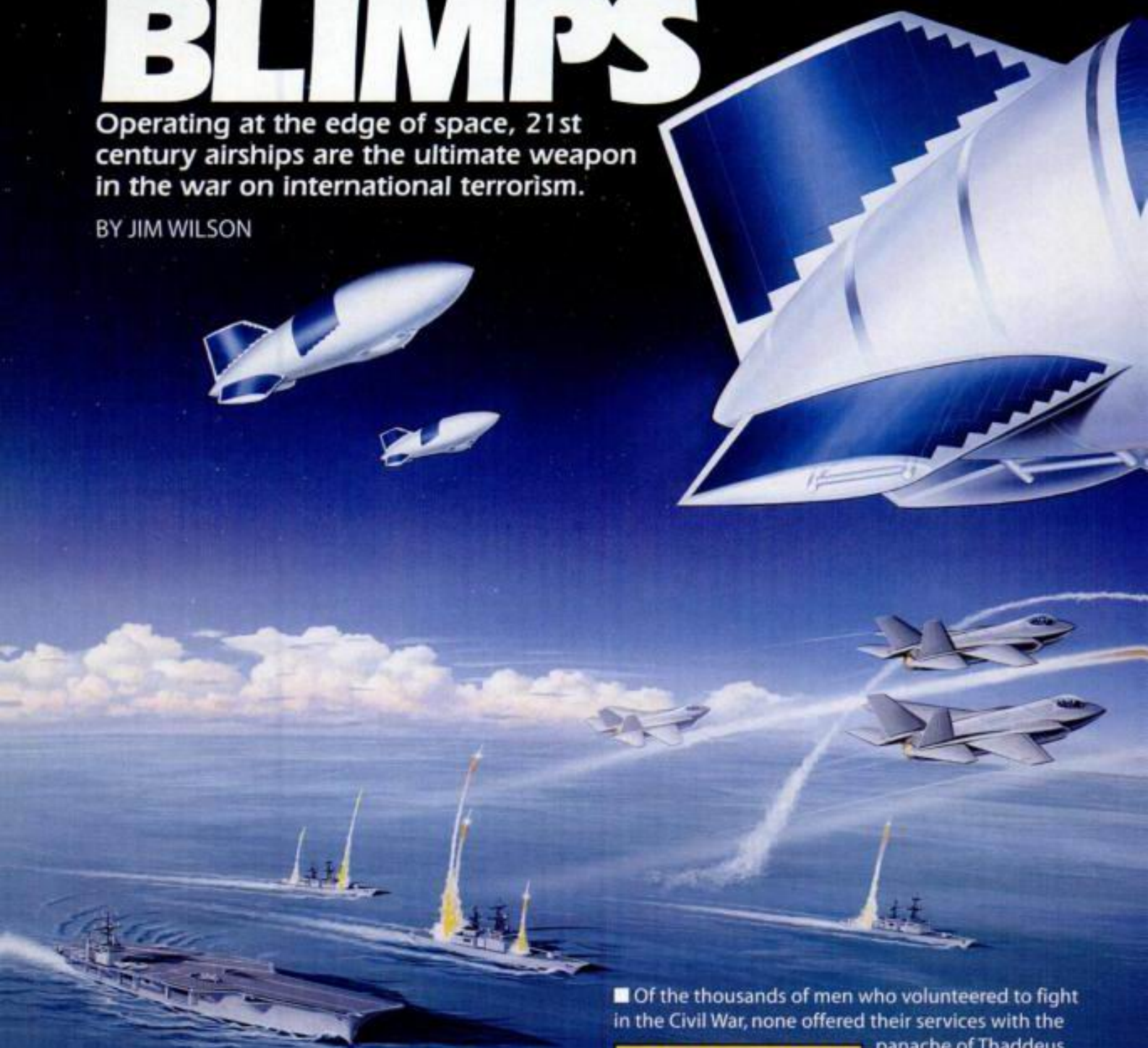
The Navy will fly the most visibly different member of the JSF family, the F-35C. Built using the same airframe

Science

RETURN OF THE BATTLE BLIMPS

Operating at the edge of space, 21st century airships are the ultimate weapon in the war on international terrorism.

BY JIM WILSON



■ Of the thousands of men who volunteered to fight in the Civil War, none offered their services with the panache of Thaddeus Sobieski Constantine Lowe. Suspended beneath a hydrogen-filled balloon floating 500 ft. above Washington, D.C., Lowe sent this message to President

COVER STORY



Lincoln: "Sir, I take great pleasure in sending you this first dispatch ever telegraphed from an aerial station." More than 140 years after that afternoon on June 17, 1861, a new generation of high-altitude, heavy-lift airships is emerging. Equipped with sophisticated ground-tracking radar, and defended with laser cannons, these 21st century battle blimps could become a crucial weapon in the

war on international terrorism. Hovering high above the fray for weeks on end, they could economically monitor enemy troops and point the laser designators that guide cruise missiles and smart bombs, released from ships and conventional warplanes, toward elusive moving targets.

"The desire to have an electronic payload in the stratosphere has been with us almost since the invention of

aviation," said Per Lindstrand, founder of Lindstrand Balloons of Oswestry, England. Located between 11 and 13 miles above sea level, the stratosphere is above all weather and is almost moisture-free. "It is also the calmest part of the atmosphere, which is very important for geostationary flight," Lindstrand said at the 14th American Institute of Aeronautics and Astronautics Lighter-Than-Air Systems Convention and Exhibition in Akron, Ohio, this past summer.

Geostationary operation in the stratosphere permits radar and other observation systems perfected for satellites to operate at 10 to 50 times the resolution of the view from space, providing highly detailed battlefield images. During tests conducted over Kosovo in November 2000, for example, the United Nations successfully demonstrated that synthetic aperture radar hung beneath a small commercial airship—the sort used for advertising—could detect buried land



PHOTO BY U.S. ARMY ENERGY COMMISSION

The Atomic Energy Commission conducted tests of blimps in nuclear combat.

mines and even live hand grenades. "The results of the radar trial in Kosovo exceeded those expected," Simon Christoforato, of the British Defence Evaluation and Research Agency, told the Akron conference.

Power To Burn

The second key to the revival of the battle blimp is power. Here, NASA

engineers and contractors have played the starring role by solving the problem that, at least publicly, stumped military designers during the early years of the Star Wars missile defense program. At that time, blimps were envisioned as platforms for testing lasers that would eventually shoot down Soviet missiles in space. In

The First Battle Blimps

As part of Operation Plumbbob tests conducted in 1957, the Atomic Energy Commission (AEC) hung nuclear weapons as large as 74 kilotons beneath blimps. The nuclear balloon era came to a close in 1963 after a pair of freak accidents destroyed the AEC's two airships on two consecutive days. On that Saturday, April 20, a blaze caused by a loose gas cap on a motor-generator set fire to an airship moored overhead. The next day, a lightning strike caused the cable to break on the second airship. It drifted across the Nevada weapons test range and out of sight of ground crews, never to be seen again.

While the AEC was experimenting with using airships to lift nuclear weapons, the Air Force was in the midst of Operation Moby Dick. This was an attempt to photograph Soviet military installations from altitudes over 100,000 ft., safely above the range of surface-to-air missiles. An internal study written in 1957, and classified secret for 40 years, concluded that free-floating balloons could not accurately



ILLUSTRATION BY GOODPASTER AIRCRAFT



photograph small targets. The job of watching our adversaries was eventually turned over to U-2 and SR-71 aircraft, and later satellites.

The military has known how to lift payloads as heavy as 15 tons into the stratosphere for nearly half a century. In the spring of 1960, Goodyear Aircraft—now part of Lockheed Martin—went public with a proposal to enlarge the 80-ft. ZPG-3W airship it built for the U.S. Navy to nearly the length of two football fields. The unnamed craft, illustrated here, would have carried 110,000 pounds.

"As terrorism grows, the more vital battle blimps become."

Inside The Battle Blimp

Future battle blimps will draw heavily on technology, such as solar cells and fuel cells developed for aerial cellphone relay stations and laser cannons designed for missile defense.

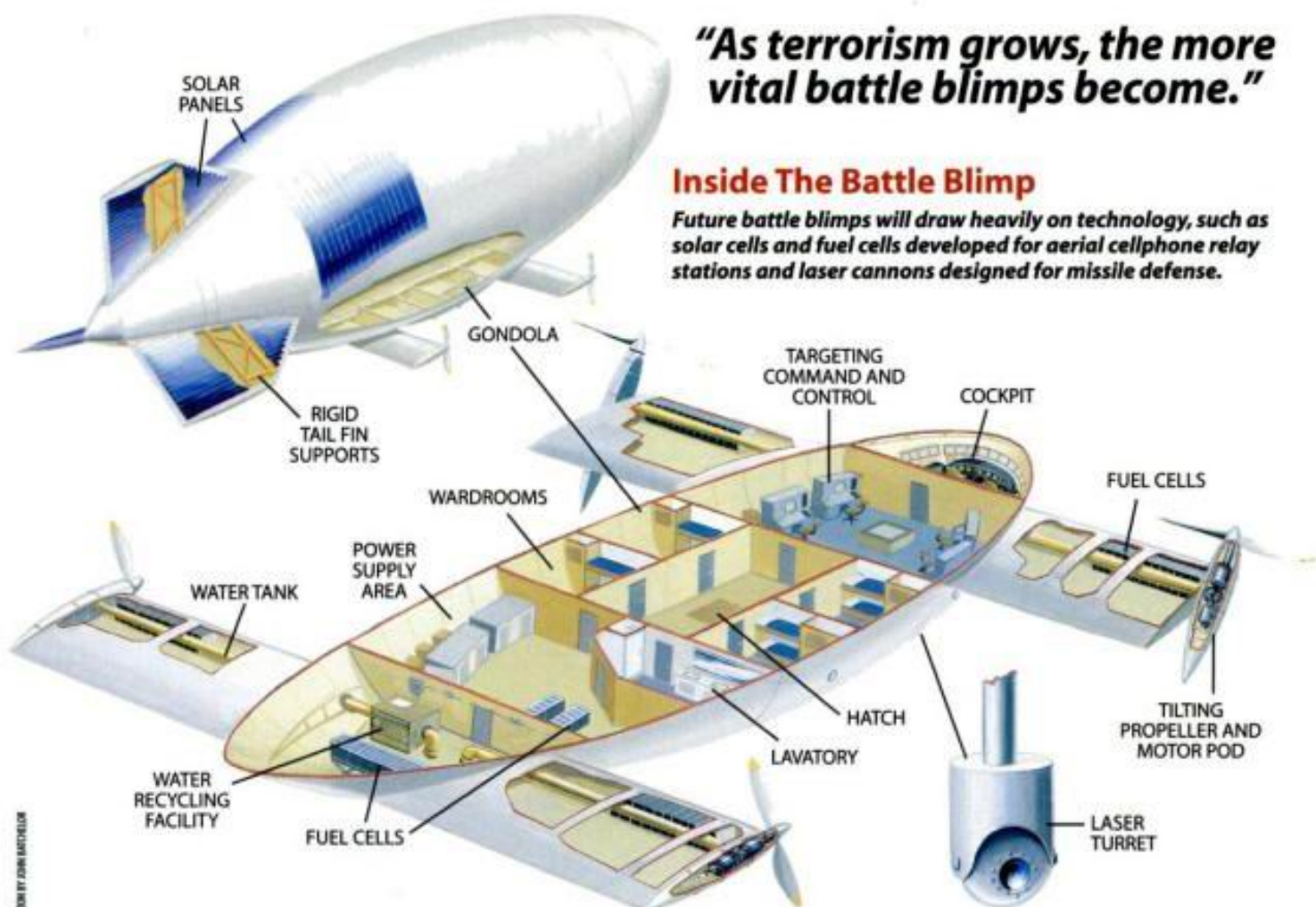


ILLUSTRATION BY JOHN BARTHELON

the early 1980s, the Pentagon funded a design study of a battle blimp powered by four piston engines, fueled with liquid hydrogen. "This obviously meant frequent refueling, which is undesirable as 90 percent of all airship accidents happen during the docking phase," Lindstrand said. The Star Wars blimp was never built.

NASA approached the fuel problem by looking to the sun. It financed research into the development of high-efficiency—30 percent plus—solar cells and, later, lightweight fuel cells. This work was eventually incorporated into NASA's Helios program, which involved building a long-endurance, high-altitude drone for atmospheric research. During daylight hours, high-efficiency solar cells power electric motors for propulsion. Surplus electricity is used to break water down into hydrogen

and oxygen, which is then stored. At night the gases are recombined in a fuel cell, producing electricity and water, which is used the following day. In an airship, the combination of solar cells and fuel cells provides an additional benefit. As the lifting bag leaks—all such bags eventually leak—lost helium is simply replaced with lighter hydrogen.

"A lot of NASA Helios technology has found its way into what we are doing," Charles K. Lavan Jr. tells *POPULAR MECHANICS*. He is the principal engineer for advanced programs at Lockheed Martin Naval Electronics and Surveillance Systems in Akron. The company has designed a high-altitude airship that can carry telephone- and Internet-switching equipment. Lavan heads a team that has come up with a design that uses nacelle-mounted, brushless DC motors to keep a blimp "on station." Hydrogen and oxygen are stored in hollow tail-structure tubes—and there will be plenty to store. High-

efficiency solar cells operate even better at high altitudes, Lavan explains. The net result is that sufficient power for both telecommunications gear and station-keeping can be obtained by covering only the tail assembly with solar cells. To satisfy the higher power requirements for radar and laser designators, and perhaps someday defensive laser cannons, designers could extend solar cell coverage over more of the airship.

Exactly how far the United States has progressed in developing a 21st century battle blimp remains a matter of speculation. The most advanced work is highly classified. Some attribute UFO sightings to a massive military balloon that has the ability to mask itself by displaying on its undercarriage a montage of stars that duplicate those overhead. What is known for certain is that the more expensive the war on international terrorism grows, the more vital the "aerial station" Lowe offered President Lincoln will become.

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Battle Island

Larger than a city, the Joint Mobile Offshore Base will keep freedom fighters safe in hostile terrain.

BY JIM WILSON

Illustration by John Berkey

Earlier this year, as the buildup for a war with Iraq shifted into high gear, American diplomats began calling on their counterparts in the Middle East and southern Europe. They asked a simple favor: permission to use local bases for attacks on Iraqi weapons factories and military installations. As the classified cables reporting on the lack of progress in working out agreements flowed back to the State Department, it slowly became evident that America had fewer friends than once thought.

DEFENSE It became equally apparent that if the United States wanted sure footing for future battles against terrorism, it would have to look beyond diplomatic arrangements. And so, almost overnight, an idea that had hovered in the shadows since the mid-1990s began to make sense. If American forces could not count on friends, they would have to rely upon technology in the form of a new type of naval vessel, a mobile offshore base.

As it is currently envisioned, the Joint Mobile Offshore Base (JMOB) would be a collection of

modular, self-propelled platforms, each measuring roughly 1000 ft. long x 500 ft. wide. Riding 120 ft. above the surface, the JMOB could traverse the ocean, driven by diesel-electric motors, at 15 knots. A modest pace to be sure, but fast enough to put a JMOB on station anywhere in the world within a month. When the individual platforms arrived, they would



Experience in constructing ultralarge vessels and deep-water offshore drilling platforms has convinced naval architects it is possible to build a floating military base by connecting individual, self-powered modules.

"A JMOB could house an Army heavy brigade of about 3000 troops."

rendezvous in international waters, beyond the range of the weapons and radar of potential foes. Connectors, perhaps like those shown on the next page, would then bridge the gaps between the platforms, creating a massive floating fortress.

A key feature of the JMOB would be its ability to adjust to various types of fighting. In the "softening up" stages of an air campaign, a JMOB would be configured as a massive air base, supporting strikes by heavy bombers that currently can be reliably based only on land. When the invasion phase of the operation began, the JMOB could be rearranged to accept commercial airliners filled with reservists. Troops could then move rapidly to shore on hovercraft and landing craft that would operate from an artificial "beach" below the flight deck. After a battle, space devoted to housing troops could serve as a floating lockup for prisoners of war and enemy combatants.

JMOB Modules

Individual JMOB platforms—naval architects call them modules—will most likely be semi-submersibles. They will ride high on the water while in transit, then take on ballast to become stable, wave-resistant islands. Building these modules will draw heavily from conventional assembly methods now used to make ultralarge containerized cargo vessels and supertankers. It is a task that BWX Technologies of Arlington, Va., says American shipyards are prepared to tackle. "They could be assembled into completed modules in sheltered waters around the Gulf of Mexico," says Bat LaPlante, a consultant who directed the

BWX Technologies JMOB project.

Modular design supports the widest possible range of aircraft, says a spokesman for the Office of Naval Research (ONR), which conducted an investigation to determine if a JMOB would be tactically useful for Navy and Marine forces. One ONR report suggests that Harrier jump jets and the Navy version of the F-35 Joint Strike Fighter could begin operations from a single module. Five modules aligned bow to stern would create a runway for conventional winged aircraft. And while all this activity was taking place on the topside flight line, the JMOB also could be handling ship-borne cargo.

Logistics are and always have been the key to success in mod-

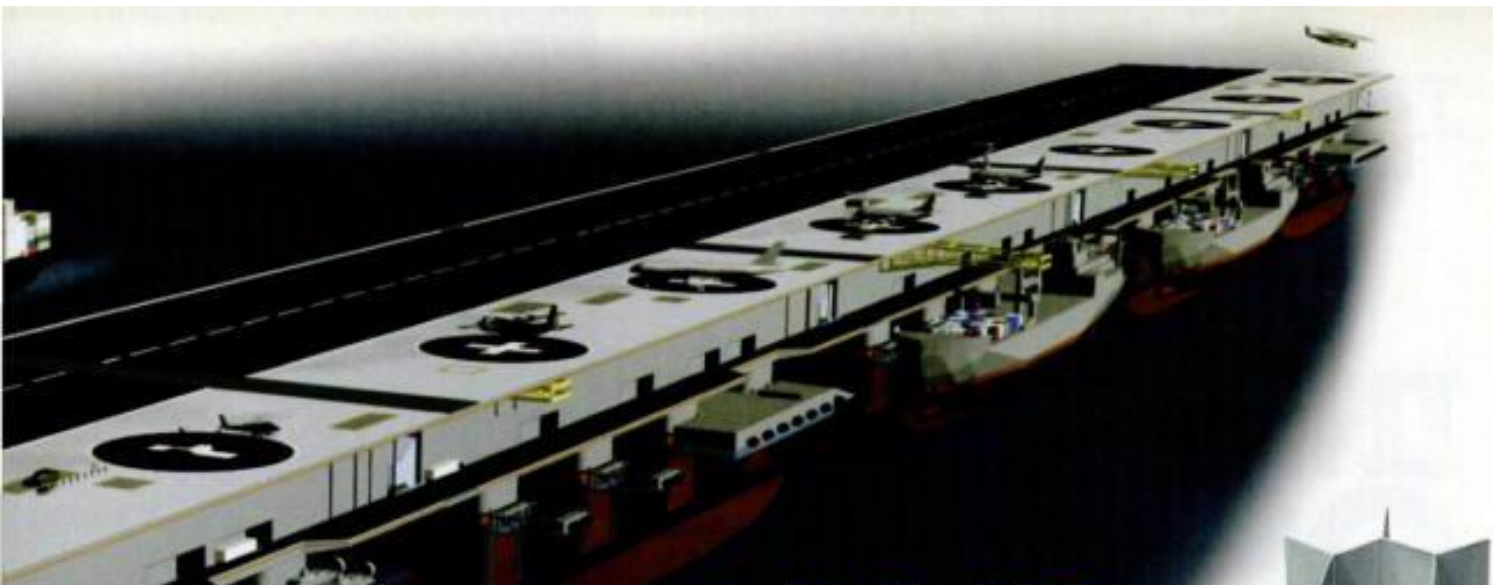
ern warfare. So there is much about the JMOB that impresses military planners. BWX estimates that a 5-module JMOB would have room for 3500 vehicles, 5000 cargo containers and 150 aircraft. Of the 5 million sq. ft. of space, 3.5 million sq. ft., roughly 80 acres, would be climate controlled. It would be so large that the military could pre-position 300,000 tons of equipment, 75 million gal. of fuel and 50 million gal. of potable water, says LaPlante. The ONR estimates a JMOB could house an Army heavy brigade of about 3000 troops.

New Design Rules

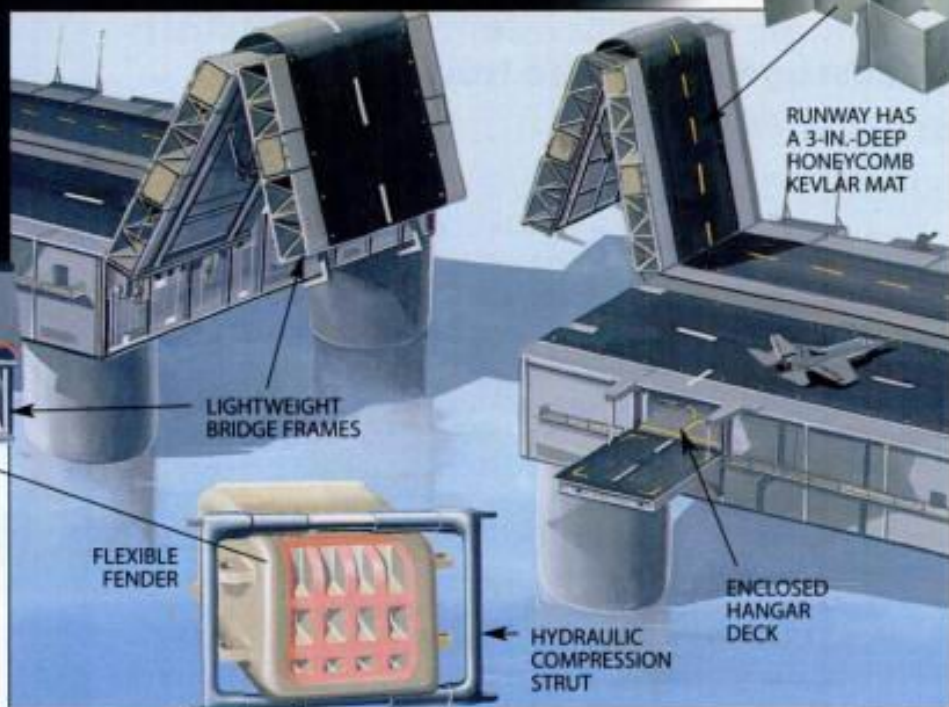
The multiple functions and extreme size of a JMOB would make it unique among floating



Hydroelastic tank testing by the U.S. Navy determined modules could stand up to heavy seas.



Inside The JMOB



Individual modules would sail to a battle zone under their own power. A GPS guidance system would keep them aligned and on station. Lightweight folding drawbridges would connect the units and create long runways.

structures, says Dennis Wright, a vice president for Houston-based Kellogg Brown & Root, which says its expertise in designing deep-water drilling platforms is the key to linking modules at sea.

The ONR mission statement that has guided the project's development since 1996 gives some idea of what is involved. In addition to being massive, the JMOB would have to be stable enough to allow fixed-wing cargo aircraft, such as a C-17, to operate in Sea State 6 conditions. Sea State numbers run from 0 (dead calm) to 12 (hurricane conditions). Sea State 6 is characterized by 22- to 27-knot winds, and white, foam-crested, 10-ft. waves with sea spray.

Experience in building large containerized cargo vessels and precisely positioned deep-water oil-drilling platforms has solved most of the engineering problems. "It is a proven commercial technology," says Wright.

The big challenge will be connecting them. And, once assembled there will be the problem of long-term station keeping during hurricanes and other severe weather conditions. Because U.S. forces train to fight in all weather, JMOBs must be capable of transferring personnel and materiel to

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shore-going vessels in conditions up to and including Sea State 3. Finally, each unit must be built to take the punishing conditions of ocean life for 40 years.

Thus far, computer simulations and hydrodynamic tests of a one-sixtieth-scale model by the Naval Surface Warfare Center have confirmed that a floating base is workable.

While the Navy has yet to sign off on the project, insiders tell **POPULAR MECHANICS** that as much as \$1 billion could be earmarked for acquiring the first building blocks of a floating fortress—as early as the end of the decade.

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ZEPPELIN'S NEW AGE OF AIR TRAVEL

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25



MAN ON THE MOON: 25th ANNIVERSARY

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RETURN OF THE ZEPPELIN

Hagenlocher of Luftschiffbau Zeppelin, the program manager for the LZ N07. That's right. Zeppelin is back.

Unknown to many, the company founded by Count Ferdinand von Zeppelin did not evaporate after the *Hindenburg* disaster of 1937. Today Zeppelin is a multibillion-dollar conglomerate with 20,000 employees engaged in construction and manufacturing. As Hagenlocher told his audience, the LZ N07 "is a phoenix for the Zeppelin organization. It is the resurrection of the airship concept."

Despite its long absence from the scene, the company has kept the balloon up, monitoring airship technology. A few years ago, Zeppelin concluded that economical, safe and durable airships would fly in today's market.

Specifically, the LZ N07—a ship just bigger than Goodyear's *Spirit of Akron*—would suit environmental monitoring, scientific experimentation, surveillance and police work. Meanwhile, a bigger version—the LZ N30—would hold 1 million cu. ft. of helium. Able to loft more than 50 paying passengers, this ship would pioneer an air-tourism business with voluminous potential.

But these two dirigibles—together tagged NT for "new technology"—aren't Goodyear retreads. Instead, they're designed to deflate airships' biggest faults: their awkwardness at the airport and the resulting high operational costs.

Airships have always resembled lumbering

dinosaurs during low-speed ground operations. Sheer mass, sprawling surface area and small props and powerplants leave them vulnerable to winds. Even with a squadron of heavyweights pulling cables, airships sometimes smash into things.

Zeppelin's solution? A 4-rotor, vectoring propulsion system. By quickly swiveling up to 120° from horizontal to vertical, the NT's two main props can counteract downward gusts or inertia. But what makes the NT unique are two more drives at the rear. One faces sideways, like a helicopter tail rotor. The other faces backward. Like the main props, it too can rotate from horizontal to vertical.

Happy landings

Thanks to this arrangement, the Zeppelin NT has pitch-yaw control that's unprecedented in an airship. By varying the props' vector and thrust, a pilot can fly a smooth, controlled approach without relying on a small army of ground workers to strong-arm his ship into submission.

Another NT novelty is its on-ground securing system. Typically, an airship dangles a single wheel, suspended on a flexible leg that extends from the gondola's center. The nose tethers to a ground mast, and the whole thing weathervanes. A ground crew

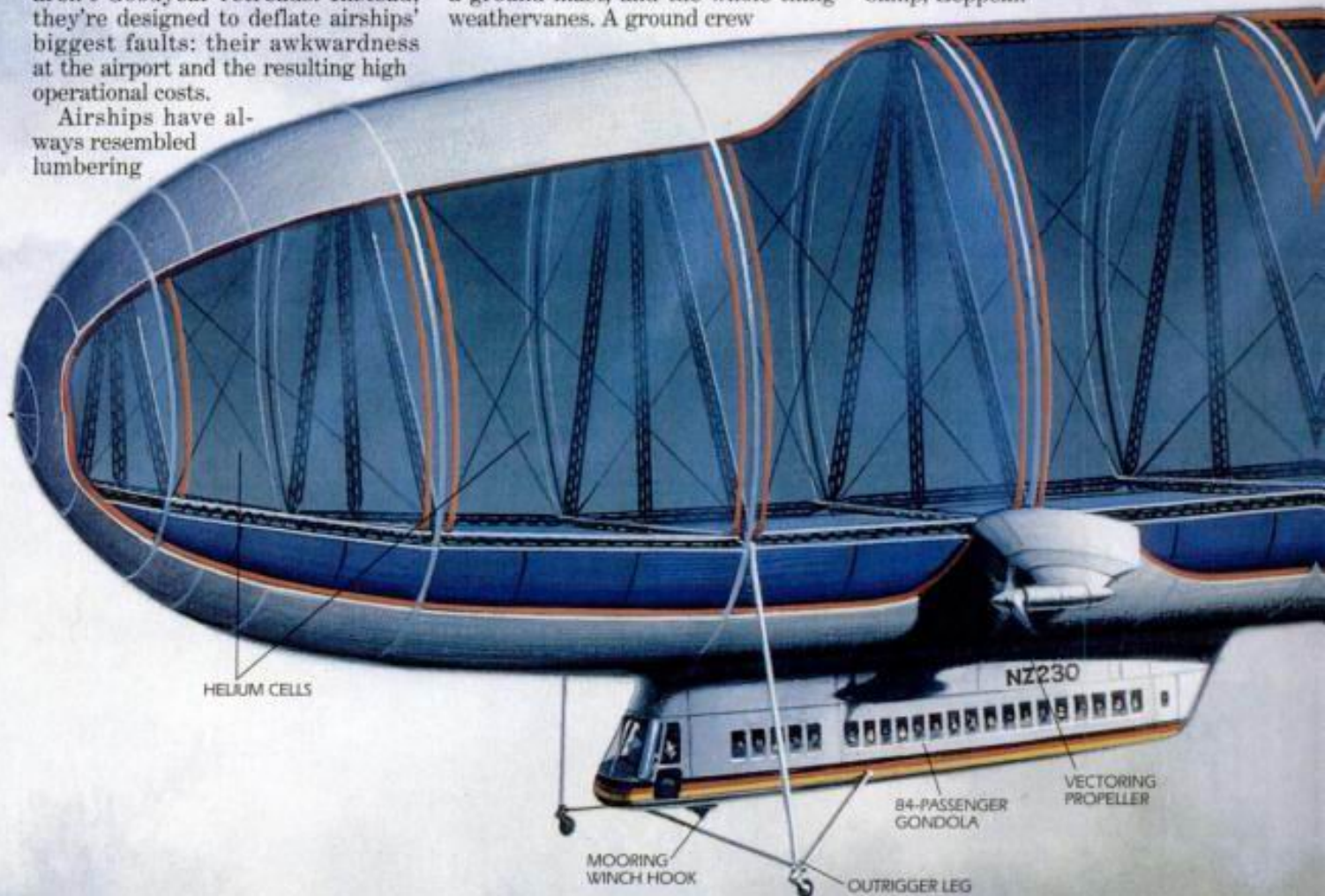
moves the ship by tugging on lines.

Zeppelin didn't like that approach. First, masts can be trouble. A mistake during coupling or decoupling can result in a speared envelope. Second, when a mast is required to secure a ship, a captain dare not venture far from one. Third, to work with a mast takes many hands, which require many paychecks, motel rooms and so on.

Hagenlocher and his engineers conceived a radically different system. The NT is equipped with two main wheels on long outrigger legs. When the ship comes in for a landing, a Kevlar cable tipped with a hook feeds out from the gondola's belly. A ground crewman slips the hook through an eyebolt on the ground. That done, the captain activates an on-board motorized winch, and the airship reels itself down.

Thus anchored, the ship can weathervane with the cable, rather than the nose, serving as the pivot point. Since this point still lies forward of the cabin and engine weight, there's no chance that a gust from the rear will nose the ship over. Meanwhile, a tail wheel prevents ground contact aft.

While a dozen or so personnel support a mast-dependent advertising blimp, Zeppelin



estimates its mastless NT needs no more than two or three people on ground chores. For the operator, that could save several hundred thousand dollars a year.

Hard core

Of course, the feature that separates the Zeppelin NT from all other modern airships lies hidden from view. A blimp maintains its sausage shape with gas pressure in an empty envelope. By contrast, the new Zeppelin NT has a forest of hard structures inside. For like all Zeppelins before it, the NT is a rigid.

Traditionally, rigid airships contained large ring-shaped girders connected by longerons, all built of aluminum. Huge gas bags lay between the rings, and thousands of tensioning wires strengthened this football-shaped framework.

The stiffness allowed designers to make old Zeppelins enormous. The *Hindenburg's* envelope loomed three times as long as a 747. And the resulting awesome lifting power meant they could load up with scores of passengers.

But size isn't everything. What appealed to engineers was the redundancy—and

thus safety—afforded by the multiple gas bags. Equally important, the internal framing offered a variety of hard points upon which to hang engines. The designers could tack powerplants and props on the tail and shift the side units off the gondola. That dramatically reduces cabin noise and improves efficiency.

There are two drawbacks, however. One is the cost of fashioning all those girders, beams and wires into a skeleton. The other is weight: The traditional structure is too heavy for a smaller airship.

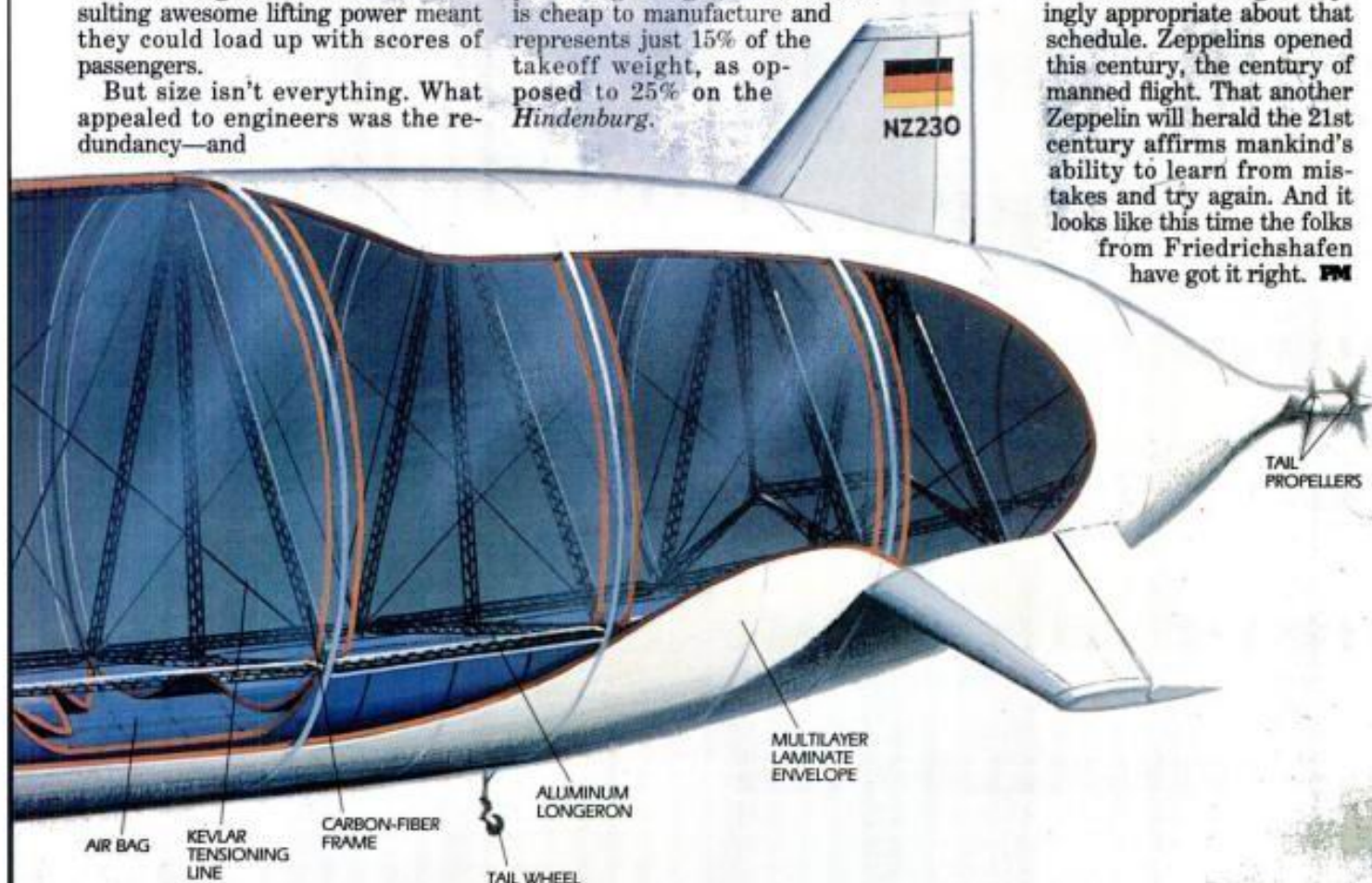
But Zeppelin engineered its way out of these problems. Hagenlocher's designers abandoned the ring skeleton in favor of huge carbon-fiber triangles connected by aluminum longerons. Tensioned with Kevlar wire, the structure is then wrapped in a multilayer Tedlar envelope. Both skeleton and envelope are load-bearing. Should either fail, the other can carry the ship's full weight. Simple and lightweight, the structure is cheap to manufacture and represents just 15% of the takeoff weight, as opposed to 25% on the *Hindenburg*.

Green light

How willing is Zeppelin to get all this innovation airborne? In January 1993, the company's executives gave the go-ahead to build the LZ N07 as a proof-of-concept demonstrator—a \$43-million decision. With a 225-ft. envelope, this mini-Zep will lift 15,320 pounds, 2 tons of which is payload. It will soldier along for 18 hours without refueling.

Before committing to the bigger LZ N30, Zeppelin will gauge the market's reaction to the N07 and assess the practicality of the new technology. If built, the LZ N30 will recall the majesty of the original Zeppelins. The envelope will be 360 ft. long, and the gondola will carry between 50 and 84 passengers. Altogether it will weigh 33 tons (without helium). Its 33,000-pound payload means it could carry enough fuel to fly for three days before heading for the pumps. If things go as anticipated, work on the LZ N30 would begin even as the N07 conducts its flight trials in 1997.

There's something satisfyingly appropriate about that schedule. Zeppelins opened this century, the century of manned flight. That another Zeppelin will herald the 21st century affirms mankind's ability to learn from mistakes and try again. And it looks like this time the folks from Friedrichshafen have got it right. **PM**



In the Zeppelin NT, the traditional ring-shaped girders are replaced with triangles. Between these frames are mounted buoyancy cells. Vectoring propellers, powered in this version by diesels, reduce the ship's vulnerability to wind gusts near the surface. Mooring winch hook and outrigger legs simplify ground operations.

AMERICA'S TOP-SECRET DOOMSDAY PLANE

Conceived to weather a Cold War apocalypse, the E-4B remains our government's ultimate refuge if nuclear-power relations turn stormy again.

BY KENNETH J. STEIN

PM Illustration by John Batchelor



● You are the president, and the unthinkable has happened. Neofascist extremists have seized control of the Kremlin and ordered a sweeping blitz into the Persian Gulf. To show they mean business, they've volleyed a dozen ICBMs at the United States. Washington, New York and Omaha, Nebraska, now lie in smoky rubble. But you were spirited away before the devastation and, flanked by top generals, now lead a tense meeting in a top-secret conference room—somewhere between Minneapolis and St. Louis, 35,000 ft. above a shattered nation. While the Pentagon and other strategic military bases are dust, a perfectly functional command center gives you every option you need.

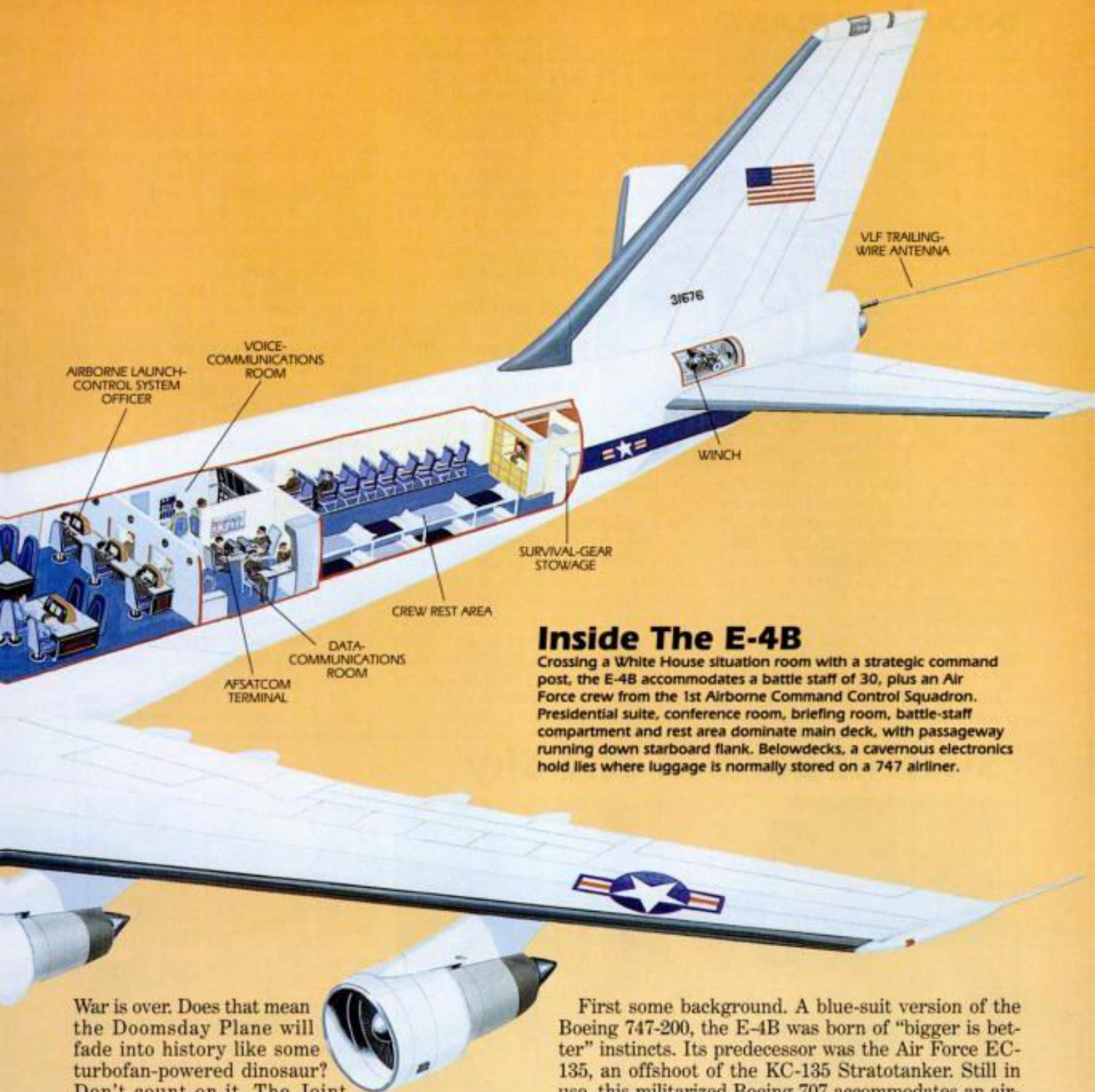
Welcome to the doomsday scenario. For this nightmare, the Pentagon hatched plans for the E-4B National Emergency Airborne Command Post, the

best of planes for the worst of times. No American military program symbolizes nuclear preparedness quite like NEACP (pronounced "kneecap" by the initiated). A White House with wings, NEACP exists solely to whisk the president and his underlying chain of command out of harm's way when nuclear hostilities loom.

As a constantly moving headquarters-in-the-sky, the E-4B would elude nuclear attack far better than ground-based or even subterranean facilities. Inside, a web of sophisticated communications and command-and-control technology would keep the finger of authority on the strategic button. While the Joint Chiefs of Staff have code-named the E-4B "Night Watch," the rest of the world knows it as the "Doomsday Plane."

True, the specter of nuclear doomsday no longer haunts international relations as it once did. The Cold





Inside The E-4B

Crossing a White House situation room with a strategic command post, the E-4B accommodates a battle staff of 30, plus an Air Force crew from the 1st Airborne Command Control Squadron. Presidential suite, conference room, briefing room, battle-staff compartment and rest area dominate main deck, with passageway running down starboard flank. Belowdecks, a cavernous electronics hold lies where luggage is normally stored on a 747 airliner.

War is over. Does that mean the Doomsday Plane will fade into history like some turbofan-powered dinosaur? Don't count on it. The Joint Chiefs will only say they are currently "reassessing" the role of the E-4B. But the Pentagon still keeps a stranglehold on information about this cherished asset. In 1987, in fact, the Joint Chiefs slapped the aircraft with a Sensitive Compartmentalized Information Facility certification—a tag that eclipses "top secret"—effectively sealing off the E-4B from the media. Still, enough is known publicly about the E-4B to reveal the extent to which our military will plan for a worst-case scenario.

In from the Cold War

Let's return to our doomsday scenario, with you in the president's shoes. Right now you'd probably be getting the rundown on your temporary new home.

First some background. A blue-suit version of the Boeing 747-200, the E-4B was born of "bigger is better" instincts. Its predecessor was the Air Force EC-135, an offshoot of the KC-135 Stratotanker. Still in use, this militarized Boeing 707 accommodates an airborne battle staff of 11, plus communications technicians and the airplane's flight crew.

In the communications network that makes up the National Military Command System, the EC-135 could—and still can—play many parts. The E-4B inherited one critical role from the EC-135: the Strategic Air Command (SAC) mission known as Looking Glass.

Looking Glass aircraft began flying on February 3, 1961, and continued for more than 30 years, ending only with the cessation of the Cold War. For all those years, an aircraft was always aloft, flying three shifts per day, around the clock. Each Looking Glass, with additional EC-135s supplying communications relays, was poised to take over direct control of bombers and ICBMs should SAC's well-publicized underground

Last Great Engineering Challenge

ALASKA-SIBERIA BRIDGE

As the Soviet Union fell, so did the final obstacle to perhaps the ultimate civil-engineering project.

BY GREGORY T. POPE, Contributing Editor
PM Illustration by Alan Gutierrez

● Big bridges are back. After years of focusing innovation on the short span, civil engineers again have far-reaching ideas in the blueprints. By the year 2000, the title of world's longest single span will have jumped from England's Humber Estuary to Scandinavia's Great Belt to Japan's Akashi Kaikyo Bridge, with its 6528-ft. main crossing. And even longer bridges loom on the horizon. Sicily to Italy? Spain to Africa? Today, neither seems too much of a stretch.

But to one maverick engineer, a final gap still beckons. It's the gap between East and West, between two worlds closer now than they have been in decades. It's a gap across time as well as space, because it spans the international date line. By geographic standards it's trivial—about 55 miles—but by engineering standards it's an ocean to cross.



PM MAP BY GRAPHIC CHART & MAP CO.

It's the Bering Strait. T.Y. Lin wants to bridge it.

Preposterous? Not so fast. Lin is no crackpot. Yes, he's daring, but he's also a decorated engineer, with the President's National Medal of Science among many honors under his belt. He's written top texts on concrete construction, designed dozens of groundbreaking structures, taught at the University of California at Berkeley for 30 years—in short, enjoyed a glorious 6-decade career in civil engineering.

But the Alaska-Siberia crossing—which Lin has dubbed the Intercontinental Peace Bridge—has been

this man's dream for 25 years. In 1969, he founded a charitable organization to finance feasibility studies. In 1986, he nonplused Ronald Reagan by handing him Peace Bridge construction plans after the president had spoken fervently on the Strategic Defense Initiative. And in 1994, as Russia reaches out to the West, the Peace Bridge has returned in a new incarnation.

Only this time it's no longer just about peace. It's about oil.

That's because the attention of petroleum companies is shifting toward Krasnoyarsk, Irkutsk, Yakut—



Intercontinental Peace Bridge would carry road and rail traffic along with oil and gas pipelines. Curved piers would deflect blows from shifting ice, while concrete would cover everything, including cables. The result: a super-rigid, weather-resistant structure.

Wakarusa 45
Teller/Front 55
Homer/Front 145

ALASKA-SIBERIA BRIDGE



Lin and Philip Chow blueprinted Gibraltar bridge with hybrid cable-stayed/suspension design. Each span would run more than 3 miles.

the vast, unexplored eastern stretches of Siberia. Already, Japan and South Korea are considering pipelines to siphon natural gas out of the region. Supplies there could dwarf the current exports into Western Europe: Last summer, geologists at Russia's Academy of Sciences prophesied that quadrillions of cubic feet of natural gas and billions of barrels of oil await exploitation in Siberia's hinterland.

This potential bonanza may just provide the financial underpinnings of the Peace Bridge. Lin wants to leverage construction by running oil and gas pipelines below the bridge's roadbed. "I've switched to an economic front," he says. "You see, the bridge will cost a few billion dollars. The road on both sides will cost \$50

billion. The petroleum resources are worth trillions of dollars. But to get to the oil and gas you need roads. And you need the pipeline."

Stepping stones

Laying the economic groundwork for the bridge will probably be harder than building the structure itself. In Lin's scheme, the bridge practically rolls off an assembly line in modules. A total of 220 spans—each a double cantilever, stayed by two pairs of heavy-duty steel cables—march across the strait, the sequence hooking slightly north at the Diomed Islands.

Every unit crosses a modest 1200 ft., except for two 1800-ft. spans for the major navigation channels east and west of the islands. The deck

consists of a double box. While road traffic rumbles across the top face in summer months, the upper box accommodates an all-weather twin-track railroad, and the lower box provides space for pipelines.

Drawing from offshore oil-rig techniques, Lin rests this modular superstructure on a series of concrete gravity piers, curved like fat bugles to fend off marauding ice floes. Each of these is towed to its position, sunk onto a base raft and weighed down with ballast. Then a huge catamaran barge floats each span to its pier. The waters themselves offer little challenge—the strait runs no deeper than 180 ft.—but as in all Arctic construction, timing is critical: Weather restricts activity to only five months out of the year.

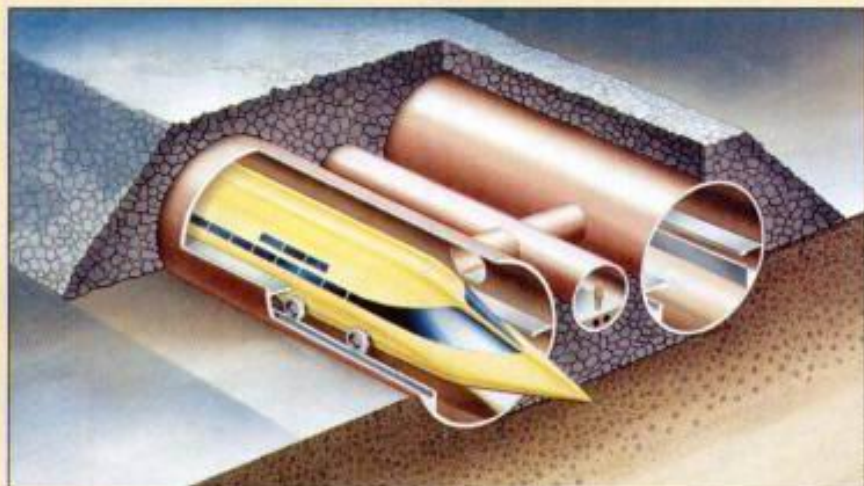
And because of the climate, concrete must swaddle everything, even the cables. "That's important from two points of view," explains Lin. "Number one, the concrete protects the steel. It simplifies maintenance in an icy area. Number two, it stiffens the bridge, so it's not just hanging from rope." Only at the deck's expansion joints would steel—coated to resist rust—see daylight.

The Peace Bridge is typical of Lin's designs: At first glance they fly in the face of logic, but eventually they fly. Case in point: an award-winning proposal for a bridge across the Strait of Gibraltar, linking Spain and Morocco. Lin and colleague Philip Chow picked an 8.75-mile route that European engineers had written off because it crossed water too deep. The Lin solution: straddling the depths with two enormous main spans that leap 16,000 ft., made possible by cable-stayed cantilevered struts that trim each suspended length to 9842 ft.—still a record span, but within reach of current technology.

Only time will tell if the Intercontinental Peace Bridge gains similar acceptance, or if fortune leads two nations to forge this link. If so, then the bridge will redefine not only geopolitical boundaries, but also the boundaries of civil engineering.

PM

Trans-Bering Express



Trains race through WorldLink tunnel made from prefab double-tube segments.

● Think the Bering Strait connection is a bridge too far? How about a tunnel instead? That's the proposal of California architect Stuart Resor—in fact, it's the linchpin of a globe-spanning railroad called WorldLink.

Resor's concept calls for an elevated track from Washington, D.C., to Paris through "the world's backdoor"—swinging up through Canada, diving below the Bering Strait and arcing across Russia and Europe. The 300-mph needle-nose trains would run on side-mounted wheels locked into grooved channels.

For the sub-strait tunnel, Resor would

adopt the procedure now under way at the Central Artery tunnel project in Boston Harbor. Prefabricated steel-tube sections are sheathed in concrete, lowered into trenches, pumped dry, buried with rubble and gasketed together.

As with the Peace Bridge, the quest for oil would fuel construction of Resor's tunnel. But Resor also envisions a day when ebbing petroleum supplies will render airline travel too costly. "There won't be any easy solution replacing aviation fuel for the long-distance haul," he predicts. Further justification, in Resor's view, for WorldLink.

—G.T.P.

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**'94 1/2
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BUILDING THE U.S.-TO-RUSSIA BRIDGE

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COVER STORY

JUMP-JET

Japan seeks to join the vertical takeoff club with a novel lift-fan design.

BY DAVID W. FREEMAN; PM Illustration by John Berkey

• You are an aircraft designer. Your assignment is to devise the next-generation passenger transport. Specifications call for a capacity of 100 passengers, a top speed of Mach 0.8, a range of 1600 miles and an operational ceiling in excess of 32,000 ft. Your aircraft must be reliable. Very comfortable. And quiet enough to meet increasingly stringent noise regulations. Finally, your aircraft must be sufficiently economical to compete head-to-head with the commercial airliners now in service.

Oh, yes—one last thing. Your aircraft must be capable of taking off and landing vertically from an unprepared site no more than 200



AIRLINER



sq. meters in size—a tiny fraction of a conventional airport runway.

If you're stumped, you're not the only one. For decades, designers in this country and abroad have been engaged in an on-again, off-again effort to develop just such a machine—a commercially viable aircraft that combines the short-hop virtuosity of a helicopter with the speed, economy and comfort of a fixed-wing jet aircraft. In other words, the Holy Grail of commercial aviation.

Yet, despite numerous promising designs, as well as a handful of prototypes and production models (most notably the Bell/Boeing V-22 Osprey now being tested for the U.S. Armed Forces), most existing and proposed VTOL aircraft have been prop-driven machines—tilt-rotors, tilt-wings and other aircraft designed for short hauls, small payloads and low speeds. Fine aircraft, in many cases, but lacking the specs to compete with other modes of intercity transportation.

If, on the other hand, you've got a few good ideas, there may be a job waiting for you in Tokyo. There, aviation designers from the National Aerospace Laboratory (NAL) are working to create just such an aircraft. Pictured here is what the team has come up with so far.

This proposed VTOL aircraft represents more than

an ambitious early step into novel aircraft technology. Says Masanori Endoh, head of NAL's VTOL development program, the aircraft will spark a worldwide revolution in commercial aviation.

"We must build this big VTOL aircraft as soon as possible," says Endoh, "because it will open the horizon for a new air-transport network suitable for the 21st century. Once we build it, we will no longer need conventional airports."

Endoh's aircraft isn't on the tarmac just quite yet, of course. Several hurdles remain uncrossed: ever-tightening government R&D budgets and certain design challenges, including development of a powerful and reliable lift fan. Moreover, even in the rosiest scenario presented by Endoh, the first flight of the finished VTOL prototype won't come for another decade, at least. But there is reason for optimism. According to Endoh, preliminary studies of the proposed aircraft's propulsion system, as well as computer analysis and wind-tunnel testing of its airframe, suggest that the NAL aircraft will meet all the criteria outlined above.

It doesn't take an aeronautical genius to appreciate the appeal of a VTOL transport. Just ask any hapless traveler who has fought heavy traffic on the road to and from distant airports, or awaited takeoff on a packed runway.

Urban planners have traditionally tried to reduce

JUMP-JET AIRLINER

such delays by adding new infrastructure—more runways, bigger terminals and higher-capacity highways around existing airports. But new construction of this type seldom provides more than temporary relief. In addition, the clearing of wooded areas and pouring of new concrete become less and less attractive as competition grows for land in crowded metropolitan areas. Already this approach is altogether impractical in a country like Japan, where small size, mountainous terrain and high population density render new infrastructure especially undesirable. Hence, it's no surprise to aviation experts that VTOL transports will likely first appear in the Orient.

The Japanese designers hope to shorten air-travel delays by concentrating on new hardware rather than new infrastructure—that is, not by boosting access to centralized airports, but by building a new class of aircraft capable of flying out of tiny decentralized airports located only a short walk from downtown districts. In the United States, the Federal Aviation Administration has already commissioned vertiport feasibility studies for 15 different cities.

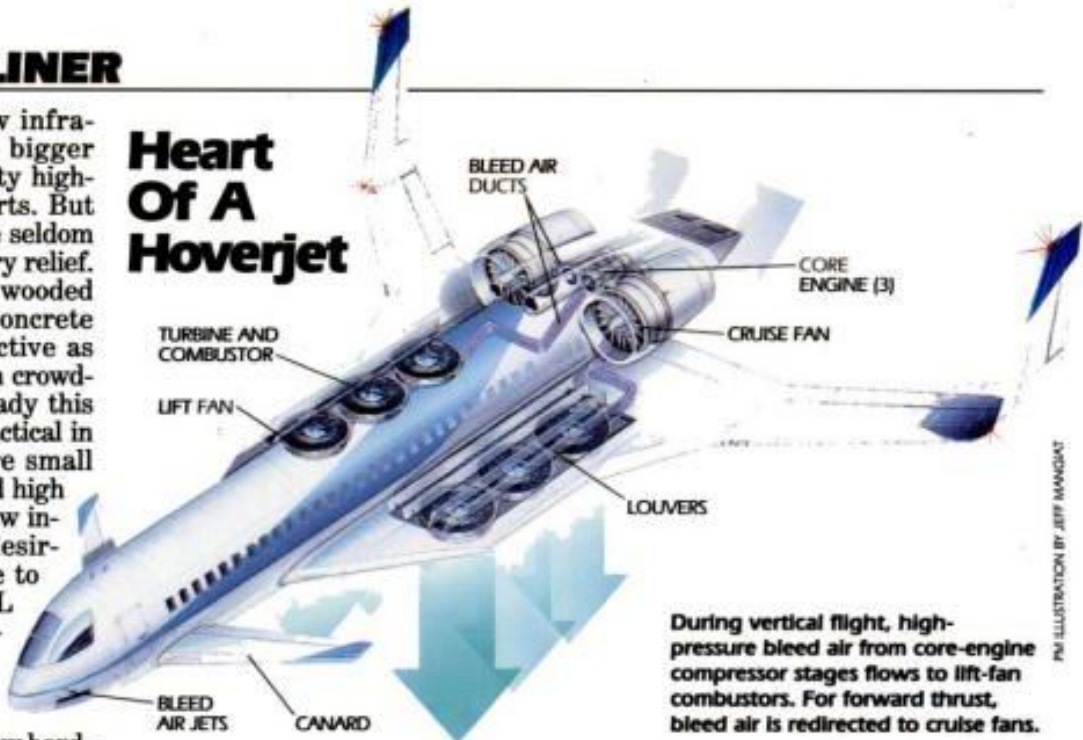
The cost of flying on the proposed VTOL aircraft remains uncertain. Endoh predicts a ticket price 20% higher than that for flying on a conventional airliner. Other aviation experts aren't quite as sanguine. Says one, the cost will be so high initially that the aircraft's only users will be wealthy tourists and companies shipping high-value cargo. However, he says, prices should soon drop to competitive levels.

As presently envisioned, the NAL VTOL transport would employ a narrow, tailless airframe, with twin canards sprouting from the fuselage just aft of the cockpit and narrow, dramatically swept wings set far aft. In place of a conventional tail, the design calls for winglets shaped alike but proportionally much larger than those found on some existing airliners. The aircraft, equipped throughout with advanced fly-by-wire technology, would be approximately 100 ft. long, with a wingspan of 79 ft.

This unusual configuration helps ensure stability—especially during low-speed and vertical operation when the absence of horizontal air-speed renders control surfaces ineffective.

"We tried many shapes," recalls Endoh. "However, to reduce the danger of uncontrolled roll, pitch and yaw, we had to make sure the center

Heart Of A Hoverjet



During vertical flight, high-pressure bleed air from core-engine compressor stages flows to lift-fan combustors. For forward thrust, bleed air is redirected to cruise fans.

of gravity was on the lift engines. That left us with just one possible design."

For reduced weight and increased rigidity, the NAL team plans to fashion virtually all elements of the structure—including fan blades and engine components—from ultralight carbon-fiber composites.

The aircraft would be powered by a unique system employing lift and cruise fans powered by a trio of aft-mounted turbine powerplants. For forward thrust, high-pressure bleed air tapped from the compressors of these three "core" engines would be routed to twin, 7-ft. cruise fans. At the center of each fan, is a combustor where fuel would mix with the bleed air and ignite. The expanding gases would spin a turbine linked to the fan by a reduction gear, producing 24,000 pounds of thrust per side.

During vertical takeoff and landing, bleed air would be ducted to six 8-ft. rotors encased within the wings and shielded on both upper and lower wing surfaces by controllable louvers. Collectively, these 200-blade rotors—each molded from a single piece of carbon fiber and each fitted with its own combustor, turbine and reduction gear—would generate in excess of 130,000 pounds of thrust.

Perhaps surprisingly, the lift fans should not be especially noisy. "Because the fan speed is very low, and because the sound produced by the one-piece fan mechanism will be extremely high-pitched," predicts Endoh, "our aircraft will be quieter than a conventional helicopter. However, just to make sure, we will use sound-absorbing liners inside the louvers. It will cause no environmental problem."

As the craft rises, the louvers work

in tandem with several small low-pressure bleed air jets positioned at several points along the fuselage to maximize low-speed maneuverability and stability. To facilitate the transition from vertical to horizontal flight, the pilot gradually redirects bleed air from the rotors to the cruise fans, simultaneously closing the louvers to seal off the rotors. Closing the louvers boosts the wings' effective surface area, thereby increasing aerodynamic lift. (In fact, the pilot can easily seal off the louvers and get the aircraft airborne using a conventional rolling takeoff.)

Once the craft reaches altitude, one of its core engines is shut down. The louvers remain closed and the lift fans disengaged until the aircraft slows for a vertical landing.

If one of the three core engines fails in flight, the two remaining engines should produce enough power to keep the aircraft aloft. And if one of the lift fans conks out? In that case, says Endoh, the fan located directly adjacent to or diagonally across from the failed fan would instantaneously shut down to preserve a balanced pattern of thrust. The aircraft could fly, he says, with only four operational lift fans.

And what if a third fan stops? "In that case," says a NASA Ames scientist, "you hope for a controlled crash."

Quips like that notwithstanding, aviation experts familiar with the basics of the NAL approach are duly impressed by the proposed aircraft's safety and versatility, not to mention its apparent feasibility. As long as Endoh can persuade his government that the project deserves additional funding, expect to hear more from the designers at NAL.

PHOTO ILLUSTRATION BY JEFF MANGAT

Popular Mechanics

JUNE 1993 • \$1.95

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**RETURN
OF THE
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Bolt-On Motor
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PASSENGER JUMP-JET NEEDS NO RUNWAY

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Takeoff Design
Creates New Age
In Air Transport

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TECH UPDATE

News Of Tomorrow's Technology Today



BOEING ILLUSTRATION

SST Mothership Could Launch Orbiter

SEATTLE, WA—Stop dreaming about a ride on the X-30. The air-breathing, scramjet-packing, single-stage-to-orbit vehicle won't be built, and officials have scaled down the National Aero-Space Plane (NASP) program to putting technology demonstrations on sub-orbital rocket flights.

But the red light that froze the X-30 hasn't stopped Boeing from proposing an ambitious 2-stage-to-orbit (TSTO) launch system. Compared with NASP, however, Boeing's proposal draws on nearer-term technology.

Stage one: a beefed-up SST derived from the High-Speed Civil Transport, the Concorde follow-on that

Boeing has been blueprinting. This mothership would climb to 30,000 ft. on six after-burning turbojets. Then its seventh powerplant, a Space Shuttle Main Engine, would ignite to hike the aircraft to 100,000 ft.

Stage two: a winged reusable orbiter, carried like a baby kangaroo in a conformal slot on the mothership's belly. Its engines would also flame on at 30,000 ft. to boost the powered climb. At 100,000 ft. and Mach 3.3, the stages would separate, with the orbiter zooming on into space.

Compared with Germany's Sanger 2-stager, Boeing's

TSTO would separate at a lower speed, so its first stage needn't be built to shake off as much aerodynamic heat.

SST-derived mothership releases orbiter, depicted here with ramjets, in Boeing's 2-stage-to-orbit concept.

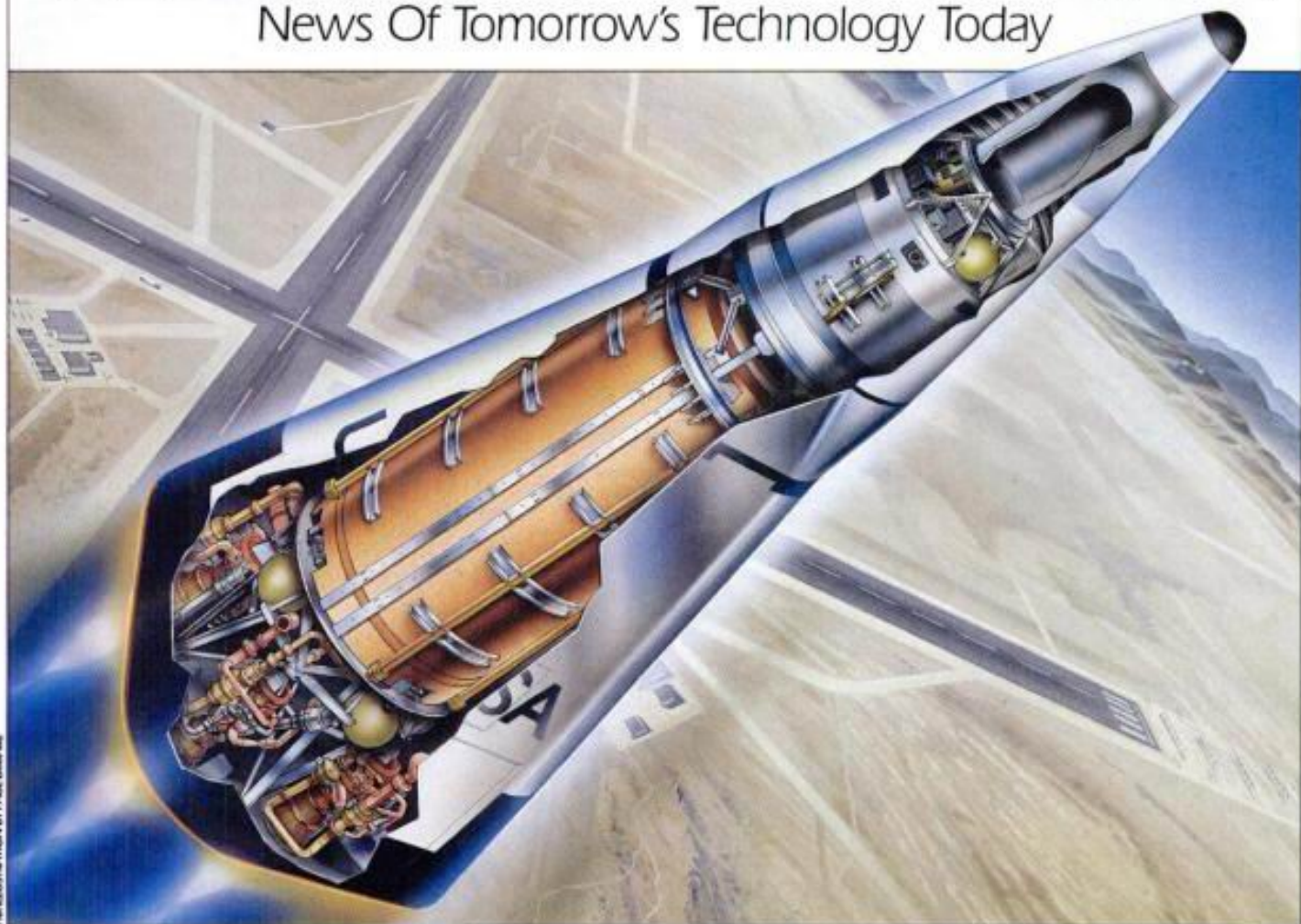
Highlights This Month

- **Fire Drill**—Extinguisher bores through stealth-plane skin to snuff engine blazes.
- **ICE On Wheels**—Germany's 175-mph bullet train comes to America.
- **Two Giant Steps For Man**—Shuttle and Titan could team up for a Moon shot.
- **Shopping For Security**—The Army scouts out armored peacekeepers for MPs.
- **Cruise Control**—*Radisson Diamond* tames rough seas with twin-hull design.
- **Surge Protector**—Holland's giant sea gates slam the door on floods.

Editor: Abe Dane
Writer: Greg Pope
Reporters: Philip Chien, Mike Fillon

TECH UPDATE

News Of Tomorrow's Technology Today



PHOTOGRAPH BY PAUL DUNN

One-Step-To-Orbit Rocketry To Take First Step

WHITE SANDS, NM—This April, McDonnell Douglas engineers plan to fire off the DC-X, an experimental rocket sculpted like a giant saltshaker. Although the vehicle will initially spring only 600 ft. into the air, it'll herald technology that may revolutionize space travel.

Single-stage-to-orbit rockets bring technical complexity to bear in the cause of operational simplicity. No rocket has ever done the circus tricks that the DC-X will be asked to perform. Yet none has been as theoretically easy to service.

In its full-up demo to 30,000 ft., the DC-X's engines must fire at full thrust for liftoff, throttle back as

the rising vehicle lightens and shut off at the top of its arc. Then they'll reignite as retrorockets, bringing the DC-X down to a gentle landing on a 50-ft. landing pad.

Four new RL-10-A5 engines, adapted for sea-level operation from Centaur upper-stage boosters, will handle this workload. Pratt & Whitney has fitted each with a throttling mechanism.

Meanwhile, maintenance should consist merely of a gas purge to flush out moisture. Ground-based "pilots" will control the DC-X through a virtual-reality cockpit.

The DC-X's sponsor—the

Editor: Abe Dane
Assistant Editor: Greg Pope
Contributors: Kaiya Andresen,
Philip Chien, Scott Gourley

Strategic Defense Initiative Organization—may fund a follow-on DC-Y, able to hoist 40 tons into orbit.

Reusable DC-X single-stage test vehicle lifts off over the launch facilities at White Sands Missile Range.

Highlights This Month

- **Message In A Battle**—Covert laser leads rescuers to downed pilots.
- **Brains Go To Waste**—Smart trash cans talk back to garbage truck.
- **Stair Masters**—Tracked robots take dangerous steps.
- **Space Saver**—New mini-jetpack rescues errant astronauts.
- **Arm Curls**—Robotic tentacle flexes mechanical muscle.
- **Life Light**—Miniature belt-pack lasers aid combat medics.



Grumman's maglev features hybrid magnet in attractive-levitation arrangement.

concept using attractive levitation, in which the train's lift magnets lie on a flange that curls underneath the guideway. Germany's Transrapid maglev uses the same scheme.

But unlike Transrapid's tight $\frac{3}{8}$ -in. clearance, the Grumman maglev keeps a 2-in. clearance between magnets and guideway. A superconducting magnetic lift coil opens the larger gap.

In addition, the lift magnets feature an iron core that confines electromagnetic fields. Meanwhile, a small third coil provides trim control and shock absorption.

The vehicle also includes a simple tilting mechanism.

Concepts from the other design teams will appear in future Tech Updates.

Here Come The New Maglevs

BETHPAGE, NY—Under the government-sponsored National Maglev Initiative

(NMI), four teams of contractors have designed magnetic-levitation transporta-

tion concepts.

One of the first to be made public comes from a team headed by the Grumman Corporation. It's the only

Heavy-Duty Robots To Draw Hazardous Duty

WASHINGTON, D.C.—Unmanned heavy equipment continues to command considerable attention from government agencies.

For example, the Air Force is developing a Rapid Runway Repair vehicle. The teleoperated machine will patch craters and clean up unexploded ordnance. Eagle-Picher Industries is building the prototype, slated for

demonstration next year.

Meanwhile, the Army and the Energy Department are chipping in on a pair of remote-control vehicles that will seek out and uncover buried hazardous waste or munitions. Working alternately over a site, the machines will perform what engineers have dubbed "scratch and sniff."

A backhoe known as the Small Emplacement Excava-



Scratch-and-sniff duo root out buried hazards (above), while Air Force machine repairs runway via remote control.

tor will do the scratching. The machine is a standard Army vehicle, its hydraulic systems modified for remote control by Oak Ridge National Labs.

The excavator's remote operator will follow data re-

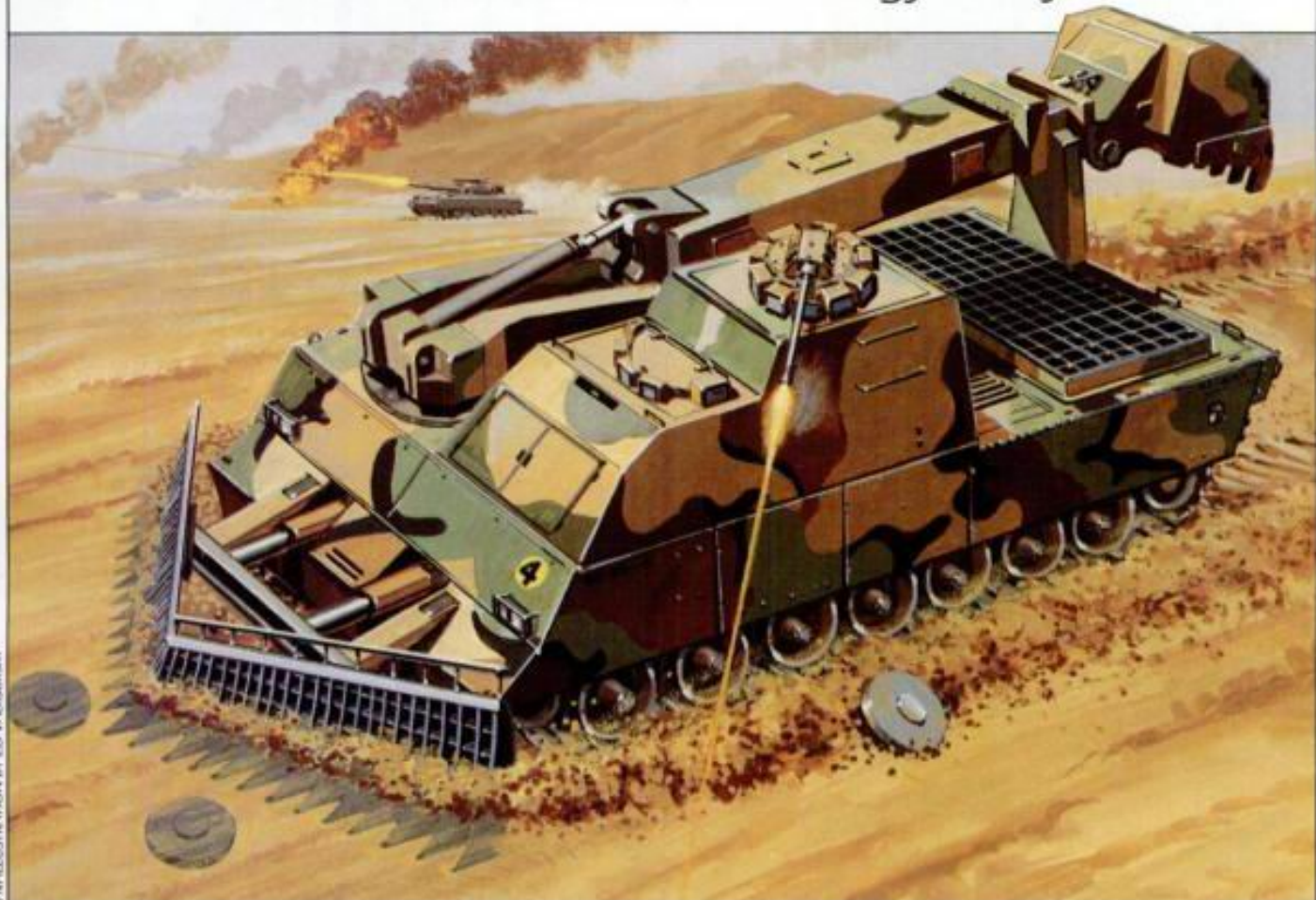
layed from the machine's "sniff" partner. Under development at Pacific Northwest and four other national labs, that vehicle is a small, largely non-metallic buggy. It will carry ground-penetrating sensors over the site to build up a 3D subsurface map. The vehicle will undergo tests in Idaho next June.



TECH UPDATE

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News Of Tomorrow's Technology Today



PM ILLUSTRATION BY ED VALIGURSKY

Army's Superdozer To Breach Future Minefields

FORT BELVOIR, VA—When the time came to penetrate the minefield laid by Iraqi forces along Kuwait's southern border last February, American and Pan-Arab forces had it easier than expected. Not only was Iraqi resistance weak, but U.S. combat engineers led the charge with technology developed for the Army's obstacle-breaching machine of the future.

The Combat Mobility Vehicle (CMV) is destined to replace the M728 Combat Engineer Vehicle and the M9 Armored Combat Earthmover. Along with its telescopic excavating arm, designed to level berms and fill tank ditches, the CMV will

feature a new V-shaped mine-clearing rake.

Driven through sand or loose soil, the rake lifts mines and pushes them to either side of the vehicle, leaving a trail broad enough for armored vehicles to tread. Last December, the Army's Belvoir Research, Development and Engineering Center rushed the rake into emergency production. By mid-February M1A1 tanks and other vehicles were sporting the device, fitted with a protruding skid shoe to keep the rake at a constant plowing depth. The CMV itself will gauge and adjust the rake's

depth automatically via a microwave-based sensor.

The Army aims to field the CMV before the year 2000.

Combat Mobility Vehicle uses rake to clear land mines. Excavator arm can lift 2 tons when fully extended to 26 ft.

Editor: Abe Dane
Assistant Editor: Greg Pope
Contributors: Mike Fillon, Bob Scheier

Highlights This Month

- **Green Power**—Plants convert sunlight into electricity.
- **Demo On Demand**—Commandos have a new tool to knock out bridges.
- **Fusion's Future**—New worldwide effort to tame thermonuclear energy.
- **Mines With Minds**—They don't just sit there, they go after their targets.
- **Blow Pipe**—The pneumatic tube mounts a surprising comeback.
- **Guarding Our Freedoms**—Bill of Rights Tour features state-of-the-art security tech.

TECH UPDATE

News Of Tomorrow's Technology Today



ILLUSTRATION BY ED VALCOURSKY

150-Mph Train To Link Florida Cities

DEERFIELD BEACH, FL—The latest plan to install a high-speed rail line in the United States calls for an electrified route between Tampa, Orlando and Miami that would be traveled at up to 150 miles per hour.

A request for proposals from the Florida State Legislature brought two bids—one from the company building the French TGV, currently the world's fastest train, and another from a consortium of 29 international companies called the Florida High Speed Rail Corp. TGV has now withdrawn from the competition.

The FHSRC train would employ technologies from numerous existing rail lines

around the world. Locomotive design is based on a Swedish unit known as the X-2, which is powered by thyristor-controlled asynchronous motors supplied with electricity from overhead lines. Lightweight, aerodynamic stainless-steel carriages will carry seating in three classes, along with dining, lounge, and bilevel snack and observation areas.

The last hurdle before construction is approval from the Florida High-Speed Transportation Commission, which is expected in '91. Operation would follow in '95.

Editor: Abe Dane
Assistant Editor: Gregory T. Pope
Contributors: Mike Fillon, Robert Scheier, Andrew G. Roe

Traveling at 150 mph through Central Florida, FHSRC train would link population centers at speeds 25 mph faster than any other rail line in the U.S. Go-ahead for construction is expected in 1991.

Highlights This Month

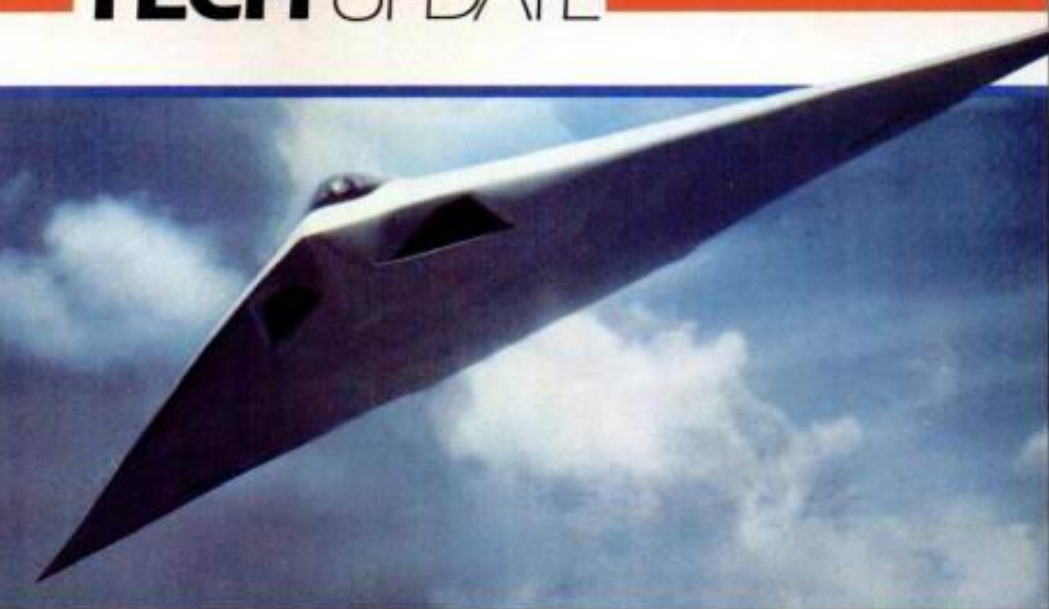
- **Crane With A Cranium**—Smart lifter outthinks dangerous loads.
- **Pegasus Flies**—Winged rocket soars into space history.
- **How To Fix The Space Station**—Maintenance hardware will be tested on upcoming Shuttle mission.
- **Call Me The Breeze**—Redesigned blades shave windpower generation costs.
- **Star Wars Strikes Back**—SDI testing continues quietly.
- **Knock, Knock**—Schwarzenegger plus special effects equal "Total Recall."

Stealthy Avenger

WASHINGTON, D.C.—The A-12 Avenger, follow-on to the Navy's A-6E Intruder attack plane, will bear a striking resemblance to the Air Force's B-2 bomber, according to a recently released artist's rendition.

Longer in range and faster than the A-6E, the A-12 will load up internal weapons bays and carry out all-weather strikes from carriers. In addition, the planes could take on jamming and anti-submarine warfare roles, as well as air-superiority missions, if armed with long-range air-to-air missiles.

In the cockpit, pilot and bombardier will benefit from



NAVY ILLUSTRATION

Navy shows tandem cockpit but offers no clues on rudders, trailing edge or wing-folding mechanism.

the first aircraft use of both fiberoptic data transmission and long-awaited military-spec Very High-Speed In-

tegrated Circuit (VHSIC) microchips.

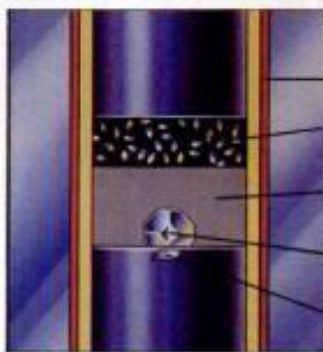
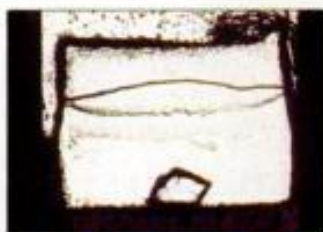
General Dynamics and McDonnell Douglas are current-

ly building six of eight Avengers for operational testing and evaluation. First flight is scheduled for 1991.



GE PHOTOS, PM ILLUSTRATION BY HANK KEN

GE researchers used a superpress (above right) to force dissolved diamond powder onto seed.



The Ultimate Diamond

SCHENECTADY, NY—Not only are diamonds the hardest things on Earth, they're also the best at conducting heat. Now General Electric chemical engineers have forged superdiamonds that outperform their natural counterparts.

The new gems conduct heat 50 percent better, and are so transparent that they absorb 10 times more laser energy without degenerating into graphite.

These proper-

ties stem from isotopic purity. GE's gems are 99.9-percent carbon-12.

GE scientists first stripped carbon atoms from all-carbon-12 methane and deposited them as a thin diamond film. After pulverizing the film, researchers dissolved the powder in a metal catalyst at tremendous pressure and temperature. The carbon recrystallized on a tiny seed diamond to grow into a carat-sized gem.

The diamonds could be used as heat dissipators on microchips or optical components for megawatt lasers.

Tank Antenna Tester

FORT HUACHUCA, AZ—The Army has a powerful new tool to determine how a vehicle's geometry affects the performance of its communications antenna.

Georgia Tech designed and built an outdoor compact antenna range, believed to be the world's largest, for the Army's Electronic Proving Ground. The range consists of a 75-ft.-dia. parabolic reflector and a hydraulic positioner capable of gripping and rotating 70-ton tanks 42 ft. off the ground.

A feedhorn at the base of

the positioner bounces signals off the reflector back toward the target. Serrations at the reflector's edge enlarge the "quiet zone" (the circle of clear electromagnetic radiation projected by the reflector), enabling entire vehicles to be tested.

The Army plans to use the range to test communications at frequencies up to 100 GHz and to examine radar cross sections of armored vehicles and aircraft.

Huge parabolic reflector bathes tank in radiowaves to check vehicle's antenna performance.



GEORGIA TECH PHOTO

TECH UPDATE

News Of Tomorrow's Technology Today



PM ILLUSTRATION BY PAUL DIMAGE

Sweden's Smyge Is The Stealth Fighter Of The Seas

KARLSKRONA, SWEDEN—Last March, a revolutionary small attack craft slipped into the Baltic Sea. The experimental surface-effect vessel combines the agility and weapons flexibility of a state-of-the-art fighter aircraft. But its name tells the rest of the story: *Smyge*, Swedish for "stealthy."

Smyge's angular hull and low-profile bridge, built of Kevlar- and fiberglass-reinforced plastics, shrink its radar signature. Antennas and mast are hull-integrated. Weapons hide internally: To fire missiles, hatches retract and launch tubes rear out. Even the 40mm gun pops from a "stealth cupola."

Meanwhile, elastic materi-

al cushions the propulsion and surface-effect machinery to minimize noise, and quiet waterjets, not propellers, drive the vessel. Infrared-damping material lines exhaust outlets, while air intakes are concealed with radar-reflecting nets.

Belowdecks at *Smyge's* center of gravity is a moon-pool, from which sailors can lower hydrophones or mine-clearing robots.

Sweden's defense establishment will use *Smyge* as a test platform for weapons, communications systems and stealth materials.

Other navies may take

note: Builder Karlskronavarvet plans to export a new line of small attack craft based on *Smyge*.

Sweden's *Smyge* combines low radar profile with quiet propulsion. Surface-effect ship's top speed is 40 knots.

Highlights This Month

- **Deep Sleuths**—Sonar and submarine robot team up to solve crime.
- **Leave The Driving To Us**—Remote-control vehicles for battlefield and mineshaft.
- **Killer-Diller Chiller**—Air conditioning the tunnel between England and France.
- **Invisible Mine**—New copper-reaping method won't scar landscape.
- **Radar Headlights**—Fords in your future will find their way through fog.
- **Patriot's Progeny**—Next-generation tactical missile busters from SDI.

Editor: Abe Danc
Asst. Editor: Greg Pope
Contributors: Mike Fillon, Bob Scheier

TECH UPDATE

News Of Tomorrow's Technology Today



BOEING ILLUSTRATION

To Space And Back In A Single Bound

WASHINGTON, D.C. — With Shuttle flights sporadic and the National Aero-Space Plane (NASP) years away, Strategic Defense Initiative planners say they need a cheap, reusable manned launch vehicle. What's more, it must fly by 1995, at least for suborbital testing. So the SDI Office has asked four aerospace contractors to conceive single-stage-to-orbit (SSTO) vehicles based on existing technologies.

The idea is to truck payloads of 5 or 10 tons into orbit for between \$100 and \$1000 per pound (depending on how often the machine blasts off). Even the high figure is one-tenth of the cost of deployment by Shuttle. The SSTO

vehicle could capitalize on work done under the Advanced Launch Development Program (see page 16) and the NASP effort.

Predictably, concepts aired so far reflect each contractor's forté. Boeing has proposed a titanium-skinned winged spaceplane, operated like a commercial jetliner. Meanwhile, Shuttle manufacturer Rockwell has proposed a vertical-takeoff, horizontal-landing spacecraft. Rocketeers at both McDonnell Douglas and General Dynamics want to build vertical-takeoff vehicles that

return tail first, firing their engines to cushion landing.

SDI's decision may come as early as this summer.

Boeing's horizontal-takeoff, horizontal-landing spaceplane is one idea for SDI's low-cost launch vehicle.

Highlights This Month

- **Flame Tamers**—The battle to quench Kuwait's oil inferno.
- **Gas Gauges**—Army's new gear to outfox chemical agents.
- **Heavy Liftoff**—NASA's coming megarockets take shape.
- **Jumbo's Big Brothers**—Plane builders eye future jets that will dwarf the 747.
- **Popular Micromechanics**—Japan's bid to commercialize tiny machines.
- **Good Vibrations**—Technology to take the chop out of choppers.

Editor: Abe Dine
Assistant Editor: Greg Pope
Contributors: Oliver Fultz, Mike Filoni,
Michael Lamm, Kathy Wollard

THE ARMY'S NEWEST KILLER CHOPPER

Lightweight, agile and invisible to radar, the Army's LH will live and fight with frontline troops.

● Flying 500 miles into a moonless night, eight AH-64 Apaches follow the Tapline Road, then wind between the canyonlike walls of the desert wadis, stealing into Iraq. Lumbering along with the quick attack choppers are a Chinook for medivac and extra fuel, and a huge MH-53 Pave Low borrowed from the Special Operations Command for its precise navigation equipment. They have 20 minutes to knock out the Ground-Controlled Intercept Station ahead.

BY ABE DANE,
Science/Technology Editor
PM Illustration by John Berkey

Success will clear the path to Baghdad for the opening air strikes of Operation Desert Storm. Failure will leave a deadly network of radar-guided missiles and interceptor aircraft to wreak havoc on allied attack planes now preparing for that first plunge.

Infrared gun camera footage

shows what happened next. Popping up out of the ground clutter, the Apaches put their laser designators on target and launch Hellfire anti-tank missiles. Radar technicians running for cover are visible as warm spots on the screen as the missiles punch into the site's buildings one by one. A spray of 30mm cannon fire and Hydra rockets completes the devastation. Hovering 2 to 4 miles away, the Apaches assess the damage, making sure the Soviet-built Flat Face and Spoon Rest



radars are out of commission, then they withdraw into the night to begin the long flight home.

Lessons of success

Ironically, this mission shows a glaring flaw in present-day Army aviation. The Apaches that carried out the raid are tank killers, heavily armored and relatively easy-to-detect aircraft designed to slug it out in a pitched battle, not to infiltrate deep behind enemy lines. The large support helicopters they required for the long-distance trek added to their vulnerability. Had conditions been a little worse, or the opposition a little more determined, the bold gambit might not have come off.

Unfortunately, nothing else in the Army inventory was up to the job. Antiquated Cobra gunships lack the sensors for night work, and the rest of the Army's Vietnam-era

fleet of light helicopters is fit for little more than scout duty.

Enter the LH

Acquiring a machine to overcome this weakness is the Army's No. 1 priority. Over the past decade, it has sought to fill the gap through a series of technology initiatives culminating in a program it calls the LH, or Light Helicopter. This April, the program bore fruit in the form of a stealthy, all-composite aircraft with flying and fighting capabilities that may revolutionize Army tactics.

The new LH design was born of a 6-year competition between two contractor teams, spurred on by the promise of \$30 billion for the winner. Boeing and Sikorsky led a team proposing a sleek, lizardlike craft with missile racks that fold into the fuselage to enhance stealth. McDonnell Douglas teamed with Bell

to put forward a manta-ray-shaped vehicle, characterized by a sharp NOTAR (no tail rotor) tail and fixed, stub wings for weapons.

Both designs met, and in many respects exceeded, the Army's requirements. But the Boeing/Sikorsky team got the nod, largely because an extraordinarily well laid-out design made it easier to operate and maintain.

Eyes of the Army

But the true measure of a combat aircraft comes in how well it carries out its mission. The LH, now known by the operational title RAH-66 Comanche, will earn its keep primarily as what the Army calls an armed reconnaissance helicopter. Maj. Gen. Rudolph Ostovich, commander of the Army Aviation Center at Fort Rucker, Alabama, and chairman of the board that evaluated the LH contenders, told PM how the

KILLER CHOPPER



Comanche will play the role.

In the hours before battle, a commander's desire for information about the enemy becomes ravenous. The normal intelligence map, peppered with battalion and company symbols, is no longer enough. "When you're going to go bust somebody up, you want to know precisely where is that ZSU-23-4? Where is that SA-6 system?" Ostovich says. Then there is no substitute for helicopter reconnaissance.

Today, this risky work is carried out by unarmed OH-58 Kiowa Scouts flying close to the ground to avoid detection. Protection comes from the guns of an AH-1 Cobra flying overwatch a short distance back.

Much of the Comanche's reason for being is that it can fly such missions alone, without anyone riding shot-

gun. This capability arises from a design that is both inherently hard to detect and capable in combat.

Built on a beam

The helicopter's strength comes from a composite box beam running up its center like a backbone. Shrouding the exterior is a tough composite hide formulated to absorb radar signals and shaped to deflect what it cannot absorb. Total radar cross-section is about 1% of that for previous light helicopters.

Because the Comanche's skin plays no structural role, anti-aircraft fire can pass right through it without weakening the airframe. The skin can also be divided up into as many access panels as needed to make life easy for maintenance crews. Under battle

conditions, for example, three soldiers at a forward area refueling point can refuel and rearm the helicopter in less than 13 minutes.

The heart of the Comanche's flying performance beats in twin LHTEC-T800 engines developed for the LH by Garrett and Allison. These 33-in.-long, 300-pound turbines crank out 1200 horsepower each, driving the aircraft to a top speed of 203 mph—8 mph better than the Army asked for.

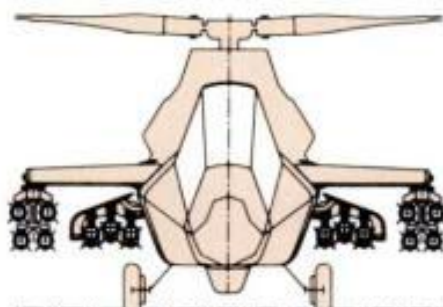
To avoid attracting heat-seeking missiles, the engines channel their exhaust through a system that mixes it with cool air sucked in through openings on top of the tail boom. Ejected through narrow slots along the boom's sides, the escaping gases are too cool for anti-aircraft missiles to lock onto. Stealth in the audible frequency range is achieved by enclosing the anti-torque fan in the vertical tail and by using a main rotor with five blades to reduce tip speed.



Armed reconnaissance: Four Hellfires, two Stingers hit targets of opportunity.



Self deployment: Drop tanks provide 1260-mile range, with two Stingers.



Heavy attack: Add-on wings make room for a full loadout of 14 Hellfires.



FAN-IN-FIN
ANTI-TORQUE
SYSTEM

Looking for trouble

For reconnaissance, however, seeing is more important than not being seen. That's where the most advanced technology on the Comanche comes in. Two sets of sensors are housed in independently rotating turrets on the nose. Aimed by magnetic head position sensors and viewed through wide-angle helmet-mounted displays, these provide enhanced vision wherever the crewmen look.

Flying from the front seat, the pilot uses a second-generation forward-looking infrared sensor mounted in the top turret to guide the aircraft at night. The lower turret contains a more complex sensor suite used by the copilot/gunner.

Prior to a typical engagement, the helicopter would rise above the tree line for a few seconds, allowing the target acquisition sensors to automat-



Mockup (above) provides a preview of Boeing/Sikorsky's stealthy design.

ically scan their full field of view, then return to cover. While the pilot repositions for an attack, the copilot/gunner uses his aided target detection and classification system to analyze the sensor data. By matching infrared signatures with a preprogrammed library, the computerized system recognizes specific types of threats, providing the gunner with a prioritized list of targets. He then configures the helicopter's systems for the appropriate weaponry, and opens the retractable weapons bays.

When all is ready, the pilot maneuvers into the open. Twin sidearm controllers linked to a fly-by-wire control system aid him in dodging threats, while the gunner places the target in the crosshairs of his helmet-mounted display and pulls the trigger.

The variety of weapons the Comanche can carry gives an indication of its

Twin multifunction displays augment helmet-mounted displays for night navigation and targeting.

many missions. In its armed reconnaissance mode, four Hellfire anti-tank and four Stinger anti-aircraft missiles can be stowed in the retractable bays. As America's first helicopter designed for air-to-air combat, the Comanche may also go into battle with as many as 12 Stingers in the bays. For ground assaults, external weapons winglets may be clipped on in a 20-minute procedure that compromises stealth, but adds space for eight additional Hellfires. A lightweight, 2-barrel gatling gun slaved to the pilot's helmet spits out up to 1500 rounds of 20mm ammo a minute in close-in confrontations.

This gives just a glimpse of the abilities built into a design so complex that it filled a 45-ft. trailer with paper. Nine years after the first LH studies began, Ostovich seems pleased with the new weapon, which should begin entering the Army inventory in 1995. "It's a testimony to the research power resident in the American R&D centers," he says. "We've got the thinking power in the U.S., and that's the real leverage."

FM



TECH UPDATE

News Of Tomorrow's Technology Today



PM ILLUSTRATION BY PAUL CHAMBER

Bailout 2000: Escape From The X-30

WRIGHT-PATTERSON AFB, OH—The National Aero-Space Plane will fly through unknown territory: Basic propulsion, flight control, sheer speed and altitude will be like nothing any aircraft has ever experienced. All the more reason to pack in some crew-escape technology should something go horribly wrong.

Air Force investigators believe the most likely technique would be equipping the craft to literally blow its own head off in an emergency.

A separable forward section would jettison from the rest of the plane, either with explosives or passively. Then a drag chute could deploy to slow the forebody,

ideally to a speed between Mach 0.7 and 1.3. At that point the crew members could bail out on modified ACES 2 ejection seats.

Researchers are currently analyzing the variables in this scenario with a computer program modified from software used in the early stages of the Space Shuttle and B-1 bomber programs.

So far studies reveal that the crew still might have to eject from the forebody at higher speeds and altitudes than are considered safe. Engineers will have to design protection systems that can withstand high windblast,

Editor: Abe Danc
Assistant Editor: Greg Pope
Contributors: Lisa Busch, Philip Chien,
Mike Filion

g-loads and aerothermal heating. Options include partially or even fully encapsulated ejection seats.

X-30 escape sequence: Forward fuselage jettisons explosively, then crew ejects from decelerated forebody.

Highlights This Month

- **Taxi To The Stars**—Latest on the Personnel Launch System.
- **Final Approach**—What happened to the YF-22A?
- **Black Hawk's Brood**—New Sikorsky chopper taps UH-60 tech.
- **Spun Glass**—Rotating furnace casts biggest mirror yet.
- **Long Shots**—DARPA's deadly new stretching ammo.
- **Three-Way Driving**—Sanyo's triple-powered electric car.

Space Taxi Takes Shape

HAMPTON, VA—A study by Lockheed's Skunk Works has confirmed the technical feasibility of Personnel Launch System HL-20 (see *Tech Update*, page 15, Jan. '91). Engineers at NASA's Langley Research Center, who developed the HL-20 concept, are now analyzing the Skunk Works' cost and production schedule forecasts.

The vehicle has evolved since it was first publicized. The HL-20's large outboard fins, originally flat, are now cambered on top for extra lift. Wind-tunnel tests and approach-and-landing simulations have shown that the HL-20 would glide stably.



The Lockheed study also okayed the rocket-assisted launch-escape system and

the use of a Titan III as a booster for an unmanned prototype.

HL-20 would go up on solid core of National Launch System.

YF-22A Is Crippled

EDWARDS AFB, CA—A fiery April 25 belly-flop landing has put the only flying F-22 prototype out of commission.

The YF-22A, built by Lockheed, Boeing and General Dynamics, was swooping low over a runway for a photo opportunity when something threw the jet into a series of bucking-bronco pitch oscillations. After about 7 seconds, the plane's tail end slapped onto the runway. Fire damaged only



Its maimed wing and fin wrapped in black plastic, the YF-22A has retired to an Edwards Air Force Base hangar.

about a quarter of the airframe, and the pilot escaped with merely a sore back.

Crash investigators are focusing on some of the capabilities that make the

YF-22A the Advanced Technology Fighter. When the bucking began, the jet was employing its thrust-vectoring nozzles and firing its afterburners while simultaneously retracting its landing gear.

Not until 1995, when engineering and manufacturing prototypes take to the air, will an F-22 fly again.

Secret Satellite Kicker

CAPE CANAVERAL, FL—The Air Force's secretly

launched DSCS-III communications satellites have some new flexibility, thanks to an extra stage tacked to the spacecraft.

Called the Integrated Apogee Boost Subsystem, or IABS, the extra rocket stage kicks its satellite into a circular geostationary orbit, then detaches. The versatile motor has an intriguing feature—it carries its own solar-power

array. That's unusual because the DSCS-III's solar panels, even folded, could generate enough power to

feed the IABS's batteries for a short period.

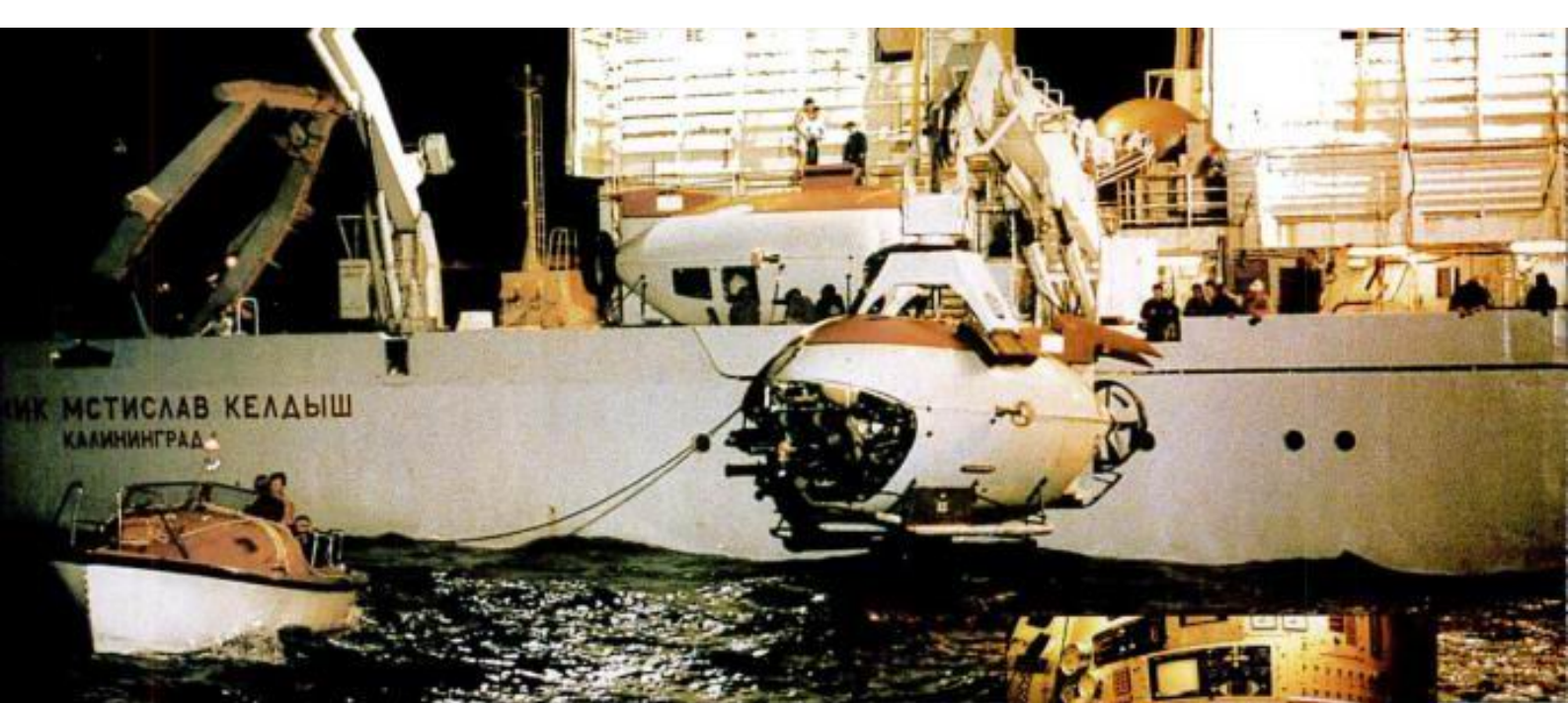
But the solar array on the little booster keeps its electronic systems operational for at least 12 days. That means 12 days can elapse between launch preparation and final positioning of the satellite in space. The extra time can stretch the launch window or allow Air Force planners to postpone a decision on placing the satellite.

Although the IABS was designed specifically for the DSCS-III, the government now owns the design and could adapt the motor to propel an all-purpose orbital maneuvering vehicle.



Apogee-boost rocket can wait 12 days before placing DSCS-III.





beneath the sea. Says "Titanica" director/producer Stephen Low, "If people can see how spectacular and beautiful it is down there, and how varied and rich the wildlife is and the geology, they will begin to think of it not as just a dark and lonely cold place, but as something that's wonderful and curious and interesting and worth preserving."

Intermingled with the expedition's cinematic agenda was a program of

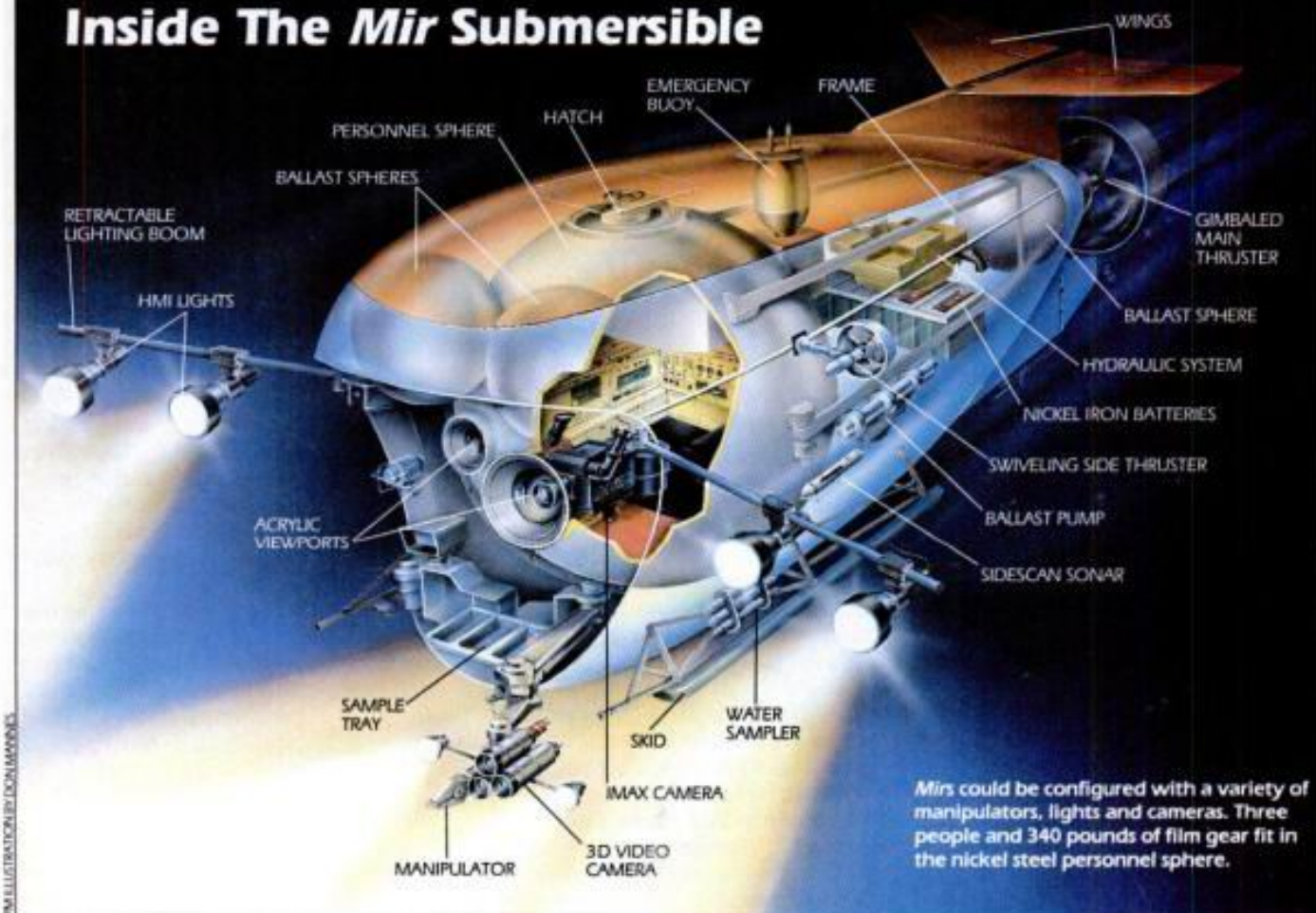
scientific observation. Not only does the Imax footage itself provide a unique record of conditions at these relatively unexplored depths, but time was taken during the dives to gather samples of the decaying wreck, the seafloor and the surrounding water. The results were unexpected. "There's a perception that the deep ocean is inert, it's isolated, it's a void," says the Bedford Institute of Oceanography's Steve Blasco, who served as the expe-



Director/producer Low prepares to dive with Chernjakk (above). Subs were launched from starboard deck cradles with the help of divers and a hydraulic crane.

EMORY KESTER/INTERNATIONAL GEOGRAPHIC PHOTOS

Inside The *Mir* Submersible



Mir could be configured with a variety of manipulators, lights and cameras. Three people and 340 pounds of film gear fit in the nickel steel personnel sphere.



Wild new look in wings: Futuristic concept for a supersonic V/STOL fighter combines radically new forward-swept wings with an advanced three-burner, thrust-boosted turbofan engine. Under study by British Aerospace, it could push speeds up to Mach 2, more than double that of current Harrier. Benefits of forward wing sweep are higher lift, lower drag, lack of wing-tip stall and improved combat maneuverability.

COMING: JUMP JETS THAT BREAK THE SOUND BARRIER

Our vertical-takeoff Harrier is a great plane, but it can't go supersonic. Now the push is on for a Mach 2 fighter that can still land and take off like a helicopter.

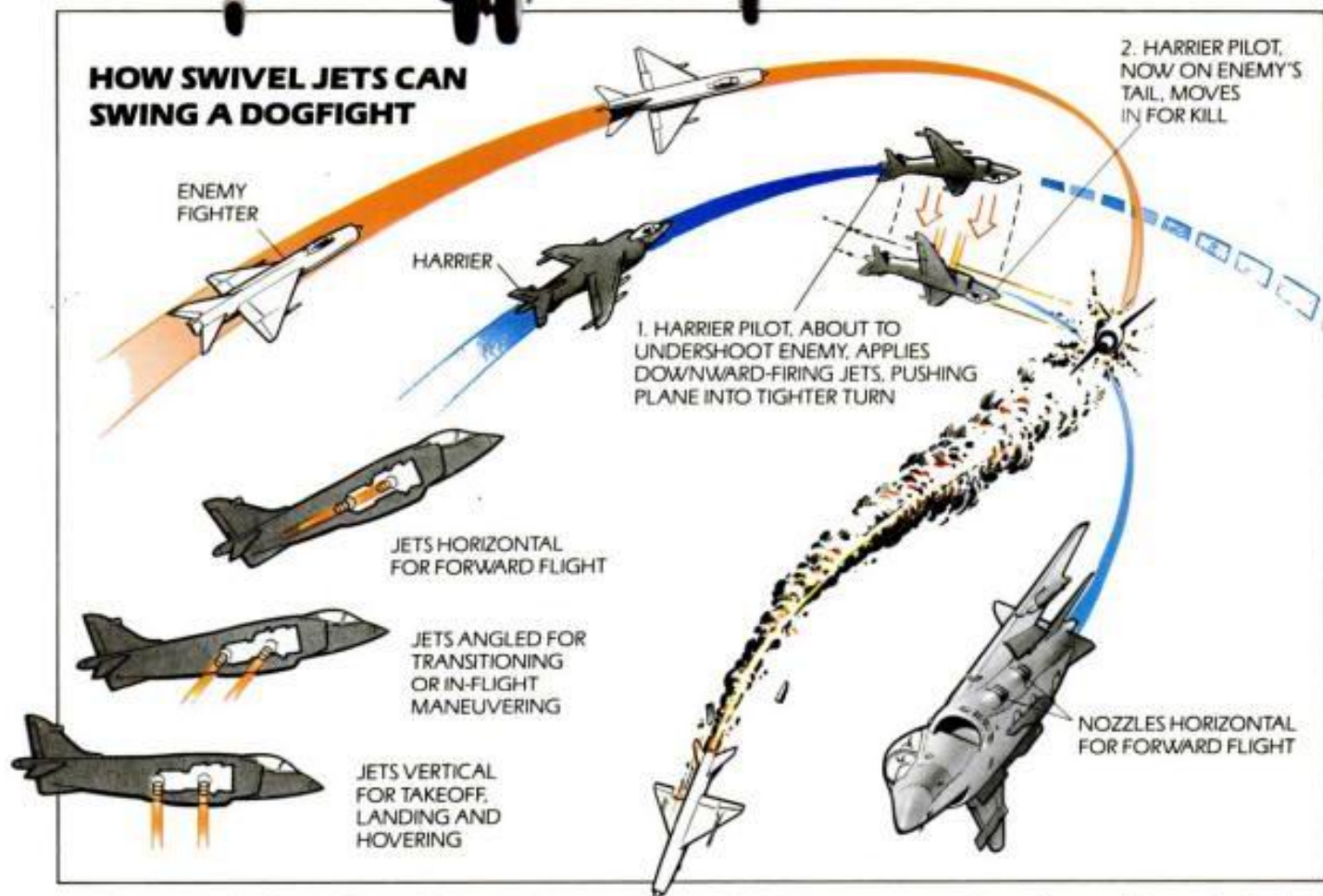
BY SHELDON M. GALLAGER
Illustrations by J.A. Lapinski and Fred Wolff

The exotic shape you see above is not a scriptwriter's prop for a space-war fantasy. It's one of several dramatic new concepts for a supersonic V/STOL fighter that could combine Mach 2 speeds in combat with the ability to stop dead in mid-air and land or take off like a helicopter.

The only V/STOL (Vertical or Short Takeoff and Landing) fighter we currently have is the famed Harrier jump jet, pioneered by the British and recently upgraded in this country by McDonnell Douglas. The Harrier, which has been in service with the U.S. Marines for more than 10 years, is a tough, versatile performer with uncanny maneuverability, but it has one critical shortcoming—it can't go supersonic. Its top speed



HOW SWIVEL JETS CAN SWING A DOGFIGHT



Steppingstone to the future: Newest U.S. jump jet, the McDonnell Douglas AV-8B Harrier II (top), is a greatly improved derivative of the earlier British Harrier with

twice the range and payload. Though still subsonic, it could provide the basis for a supersonic version to come. Diagram shows how downward-swiveling thrust

nozzles make possible vertical takeoffs and landings and also permit trick moves in combat, such as deceptive jump-turn in this dogfight sequence.

is Mach 0.93, or about 690 mph, putting it at a disadvantage when striking deep at distant targets or when tangling with enemy fighters of twice the speed.

Somewhat embarrassingly for the West, the Soviet Yak-36 Forger, a V/STOL fighter/bomber comparable to the Harrier, has a reported speed of Mach 1.1—not a great deal faster than the Harrier, but definitely and disturbingly supersonic.

The need for speed

There was a time when jump jets were looked upon as curiosities, some-

what like the gifted child who's a whiz at math, but not very good on the football field. They were regarded as useful for a few very specialized jobs, but not really able to play in the big leagues.

Now this thinking is changing fast. The startling success of the Harrier in the hands of British pilots at the Falklands in 1982 proved it could go against technically superior opposition even with its subsonic limitation. A supersonic version would have been even more effective.

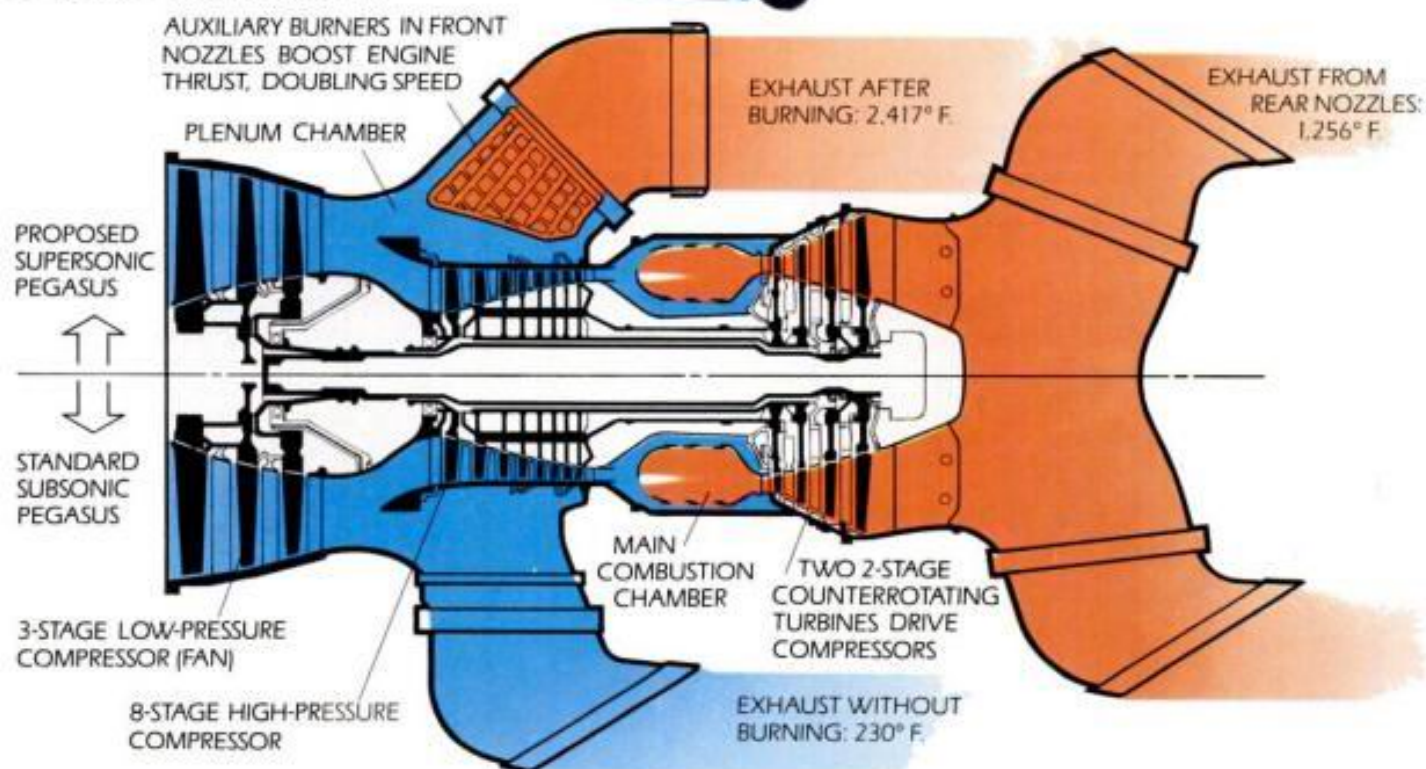
Add to this such grim realities as the soaring cost of giant supercarriers needed to handle conventional jets, the

ease with which airfields can be rendered useless through new mass-destruction bombing techniques, and Russia's ominous lead in V/STOL technology. All these factors combine to make the development of a supersonic jump jet an imperative need for U.S. and NATO security.

A Harrier can land and take off in a space no bigger than a tennis court, enabling it to operate from jungle clearings, battle-damaged runways, short makeshift airstrips, even a country road. At sea, it can be handled by small, fast assault vessels, easily converted cargo ships and low-cost "pocket carri-



HOW PCB PRODUCES SUPERSONIC THRUST



Modified Harrier, called the AV-8SX (top), will test feasibility of using new Plenum Chamber Burning (PCB) to give supersonic thrust. Diagram above shows Rolls-Royce

Pegasus engine divided into two halves. Lower half represents current subsonic powerplant without PCB. In upper half, more fuel is burned in plenum chamber

ahead of main combustion stage. This raises exhaust-gas temperatures in two front nozzles to a sizzling 2,417° F., boosting thrust to supersonic Mach 2 range.

ers" without all the catapult launchers and arresting gear that conventional jets require. Moreover, with jump jets, a carrier doesn't have to alter course to put its deck into the wind as it does to launch and recover today's aircraft, and landings and takeoffs can occur simultaneously, without one interfering with the other.

A hotter Harrier

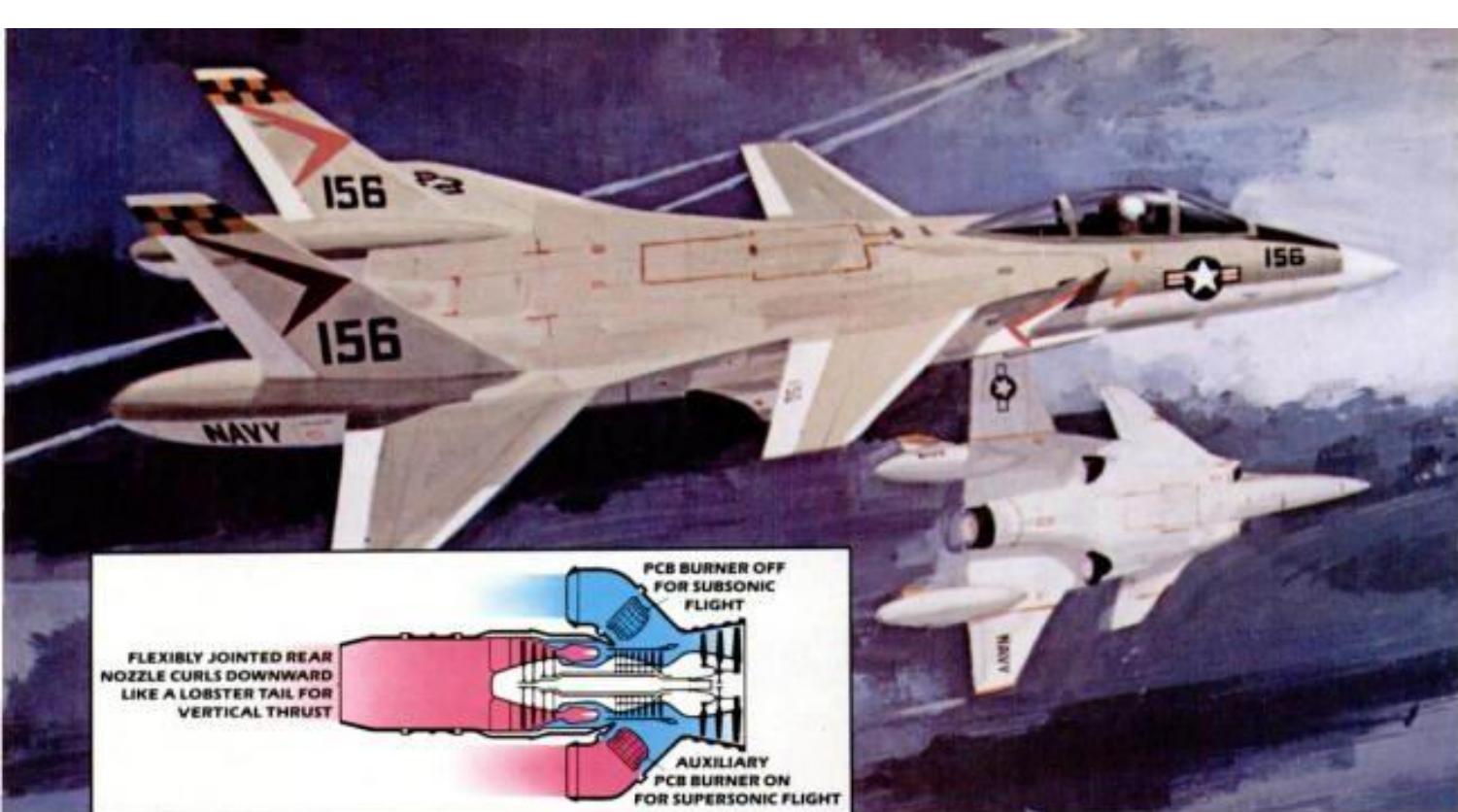
Our newest jump jet, the AV-8B Harrier II developed by McDonnell Douglas, is a greatly improved derivative of the earlier British AV-8A that could become a steppingstone to an even

more awesome supersonic version. Although it's powered by the same Rolls-Royce Pegasus engine as the AV-8A, it has twice the range and payload capacity due to a larger high-lift wing, is considerably more agile in combat, and carries advanced avionics that give it new all-weather capability as a deadly ground-attack fighter/bomber.

A sophisticated laser-guided fire control system automatically calculates the range, bearing and slant angle of a target, tells the pilot what course to fly, then releases the bombs or missiles at the precise instant to assure a hit. A hands-off, blind landing system also

enables a Harrier pilot to set the plane down in the vertical hover mode in any weather, day or night, without his touching the controls.

The Pegasus turbofan engine is a marvel of engineering ingenuity. It consists of a three-stage low-pressure compressor or fan, an eight-stage high-pressure compressor, and two separate two-stage turbines turning in opposite directions on concentric driveshafts. One turbine drives the first compressor clockwise, while the other turbine drives the second compressor counter-clockwise. The reason for this tricky counterrotation is to cancel out gyro-



Dramatic Rolls-Royce concept for a supersonic V/STOL jet (above) features movable canard foreplanes, plus a new three-nozzle engine to replace Harrier's current four-nozzle arrangement. Auxiliary PCB

burners in front nozzles provide added thrust for supersonic speed, but can be shut off during subsonic flight to save fuel. Advantages: simpler engine layout, lighter weight, better-balanced thrust control.

scopic forces that would make the Harrier difficult to control in the delicate hover mode if all engine parts were spinning in the same direction.

Four swiveling nozzles, two on each side of the engine, direct the pressurized exhaust gases up or down in a process known as thrust vectoring. Tilted downward, the nozzles produce lift for vertical landings and takeoffs. For forward flight, they swing backward to provide horizontal thrust.

Thrust vectoring can also be used in aerial combat, permitting abrupt changes in speed and direction to fool an enemy. By applying downward thrust in flight, a Harrier pilot can push his plane into a tighter turn to intercept a faster quarry, or he can use reverse-thrust braking to force an unsuspecting pursuer to overshoot him and suddenly become the target instead of the attacker. Such deceptive tactics enable a Harrier pilot to outfly a normally superior opponent.

Next step: supersonic

The new AV-8B Harrier II, now in production, is scheduled to go into service with the U.S. Marines next year. Meanwhile, the search for an even more potent supersonic version is already under way. The U.S. Navy and Air Force, until recently lukewarm to the V/STOL idea, are now eagerly eyeing the prospect of a supersonic jump jet that could eventually fulfill all the functions of conventional fixed-thrust fighters, both on land and at sea, without the need for 2-mile-long runways and 4-acre flight decks.

Fortunately, supersonic capability may not be as far off as it once seemed. Rolls-Royce is working on a method,

(Please turn to page 96)



Modified Air Force F-15 (above) is fitted with swiveling thrust nozzles and canard mini wings to test effectiveness for STOL operation. Though it can't move straight up and down like true V/STOL jet, it lands and takes off

in half the distance normally required. At the top is Boeing's proposal for advanced supersonic STOL fighter. It also has swiveling thrust nozzles and canards, plus recessed missile racks to lessen drag.

Aviation

Airborne octopus

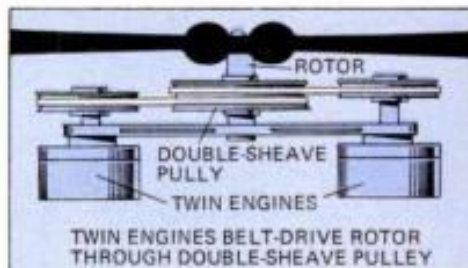
It resembles a huge, steel-tentacled octopus that's gone berserk. Actually, the strange machine shown here and on this month's cover is an eight-rotor helicopter, a prototype for what could be the world's largest, most powerful flying crane. The exciting new concept, unlike any present heavy-lift cargo copter, is the work of Dr. Igor Bensen, whose company, Bensen Aircraft Corp. (Box 31047, Raleigh, N.C. 27612), manufactures the renowned little home-built Bensen Gyrocopter.

Why the eight rotors? It's a matter of simple arithmetic. The maximum practical lifting capacity of any single rotor—no matter how big—is limited to about 20 tons. To increase lift, you must add rotors—in Bensen's case, many. His eight-rotor design, at 20 tons per rotor, will have a potential payload capacity of 160 tons—enough to carry two of the Army's mammoth new 58-ton M-1 battle tanks, with plenty of lift to spare. (The current aerial cargo-lift record is 44 tons, held by a twin-rotor Russian craft.)

Bensen's initial effort, however, is more modest: The eight rotors in the first version planned will lift 5 tons each, or a total of 40 tons. The "fuselage" is merely an unsophisticated framework of criss-crossed beams, looking much like a tic-tac-toe grid, with a rotor at either end of each beam. In the full-scale production model, the pilot and controls will be enclosed, but only by a rudimentary cab similar to those on farm equipment. There's nothing fancy to add weight and expense.



Proposed eight-rotor helicopter lifts 40 tons, has payload potential of 160 tons, world's largest. Simple, gridlike design keeps cost low. Inset shows how rotor is driven by two engines.



Scaled-down prototype in first test flight. Trickiest job: coordinating 8 rotors, 16 engines.

Because of this bare-bones simplicity (the rotors are the only aerodynamic elements in the entire craft), projected cost is low—less than half that of a conventional helicopter possessing a comparable capability.

Even more surprising than the eight rotors is the fact that each set of blades is powered by two engines, making up a total of 16 independent powerplants. Each pair of engines drives its rotor shaft through a simple belt-and-pulley ar-

rangement with overrunning clutches, like those on a kid's go-kart (see inset drawing above). If either engine quits, the rotor will continue to produce lift, providing backup redundancy for safety.

Cruising speed is deliberately limited to 80 mph, eliminating the need for costly streamlining—the airframe is what pilots call "real dirty." Synchronization of controls for the eight rotors and 16 engines—the big trick—is done automatically, though details

on just how this works are predictably being kept a secret.

Bensen plans to market his giant skyhook in separate modules, each consisting of a two-rotor section capable of lifting 10 tons. Any number of sections can be joined together like Tinker Toys to produce an aerial crane of virtually any capacity. A radical departure? Well, for Bensen, not really. After all, his tiny, one-man, build-it-yourself Gyrocopter also comes in pieces.

SEPTEMBER 1982 \$1.50

Popular Mechanics

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OUR MIGHTIEST FLYING LIFTER

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Pressure-packed WASP challenges ocean depths

A fish out of water has only two options. It can survive if it can learn to breathe air, or it can carry its own supply of water.

These options are reversed with humans in highly pressurized water, say around 2,000 feet beneath the waves. Either they learn to stand the pressure (as volunteers at Duke are learning to do), or they cart surface pressure down with them.

The WASP diving suit illustrated on this page is one of the latest pieces of gear designed to drop humans to depths of thousands of feet in protectively pressurized containers.

While it takes days to get to target depths using Duke's system of exotic breathing gases and creeping pressurization, people inside the 6-foot, 8-inch WASP can plunge immediately to a depth of 2,000 feet. They work there under one atmosphere of pressure, inside a tough shell of fiberglass-reinforced plastic. Foot pedals (similar to foot dimmer switches on cars) control electric thrusters for speeds up to one knot. When work is done, 12-mm cable hauls the WASP (which weighs 900 pounds in air) back up without decompression.

WASP's maker, Oceaneering International of Houston, tells us that amateurs can learn to use the \$250,000 to \$500,000 WASP after about half an hour of training. One of the hardest tasks, initially, is correcting for the magnification of the scene outside through the 2-inch-thick plexiglass.

The suit has some other disadvantages. It can't straddle large pipes the way a diver can, for instance: It has no legs. Its mechanically run manipulator arms are not as dexterous as a diver's arms and hands.

But the WASP is great for pipeline inspection. Its operators avoid the risk of the bends, the boredom of decompression, the panic of the fish out of water. "It works fine," a spokesman for Oceaneering says, "even for people who don't like to swim."

PM art: Ed Valigursky



WASP diving suit is dropped into the sea on a cable, but safety systems on board enable it to function even if cable is cut. Diver could activate battery to operate thrusters. Transducer (at rear of suit) permits voice communication via sonar system. In service since 1978, WASP is used for inspection work.

FUSION-We're Harnessing The Power Of The H-Bomb

Once, fusion power seemed unlikely. Now, we wonder: Which fusion system—magnetic or laser—will go on line first?

by Hans Fantel

The cheapest and most plentiful fuel on earth would be water—if you could burn it. That's no longer a pipe dream. From the way it looks now, we may soon have practical fusion reactors to liberate the atomic forces in seawater. The world would then have a virtually boundless source of energy.

Atomic fusion—the principle basic to the use of seawater as fuel—has been known since the dawn of the atomic age during World War II. But so far, no practical fusion device has been built (unless you consider the hydrogen bomb as practical). But two gigantic research projects—one at Princeton University, the other at the University of Rochester—are finally getting within spitting distance of producing useful energy from fusion reactions.

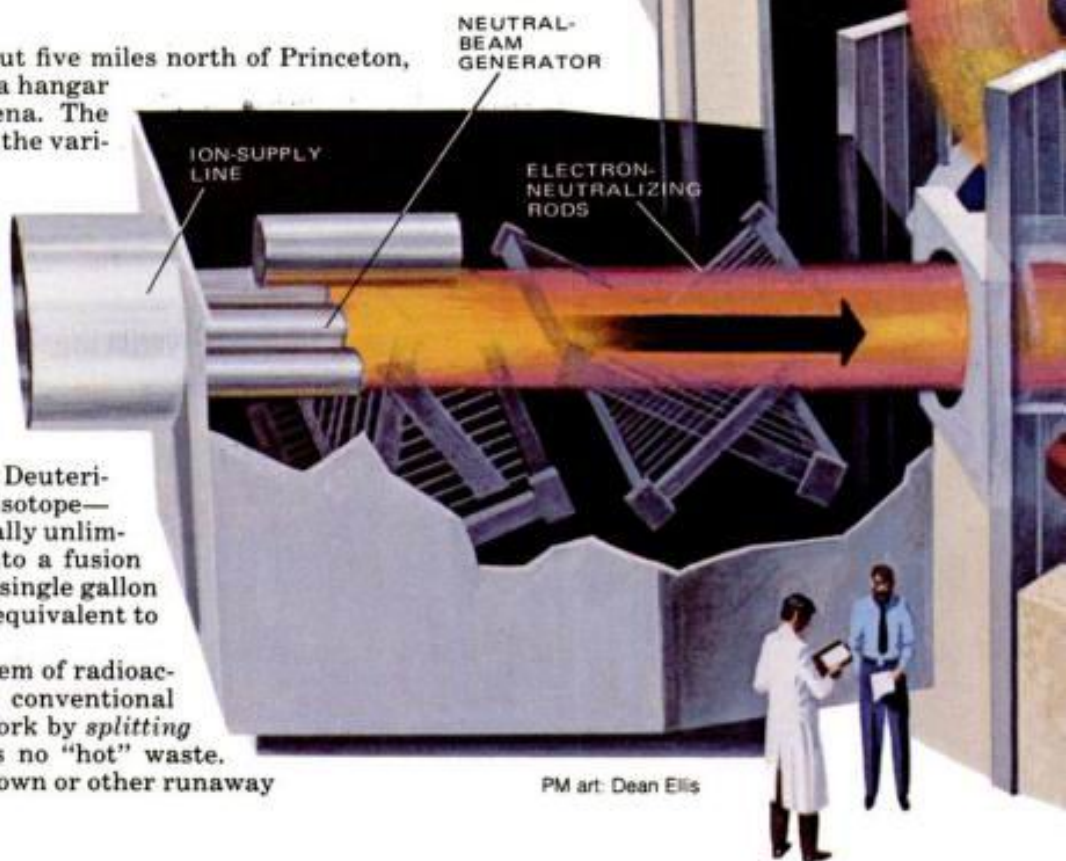
The two schools are taking different tacks toward this goal. Princeton uses a method called magnetic fusion; Rochester uses laser fusion. In the competition to deliver huge quantities of usable power, this is where development stands today.

Magnetic fusion

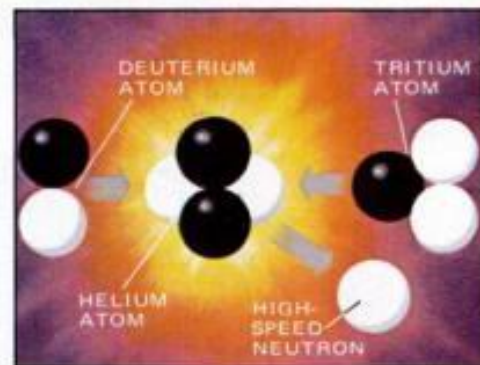
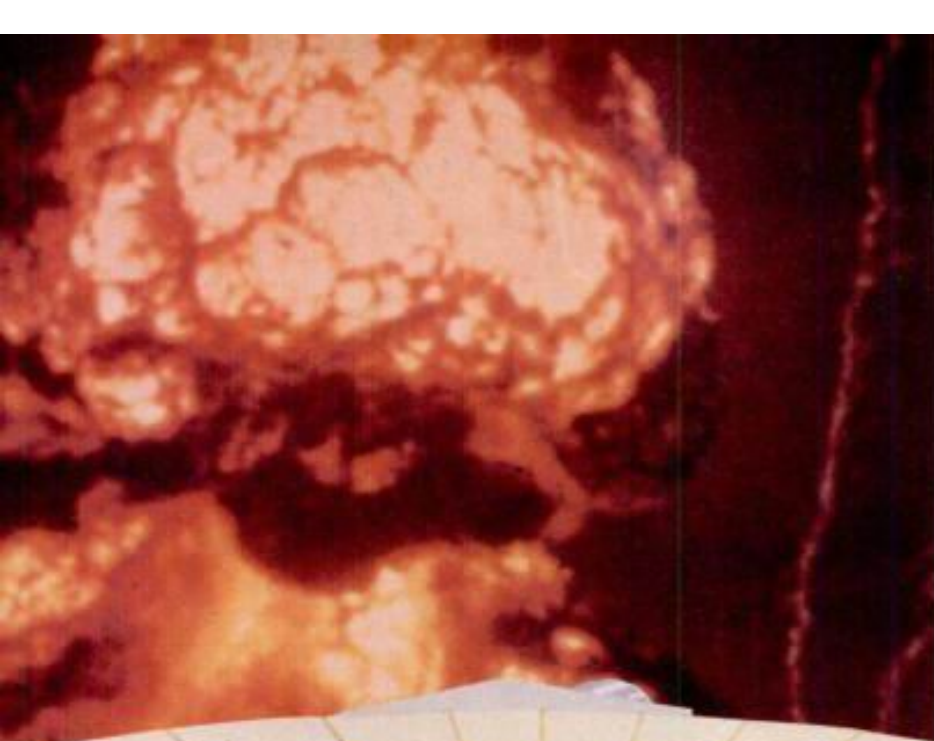
In a former cow pasture about five miles north of Princeton, N.J., a herculean machine fills a hangar space as big as a sports arena. The water-cooled cables connecting the various parts are as thick as a man's thigh. At the center of this vast metal jungle is a huge, ring-shaped tube, resembling an outsize doughnut. It is inside this circular tube that the energy-liberating reaction takes place.

Called the Tokamak by its Russian inventors, the machine uses deuterium as raw material for energy production. Deuterium is a form of hydrogen—an isotope—that's found in water in practically unlimited quantities. If triggered into a fusion reaction, the deuterium from a single gallon of water could produce energy equivalent to about 300 gallons of gasoline.

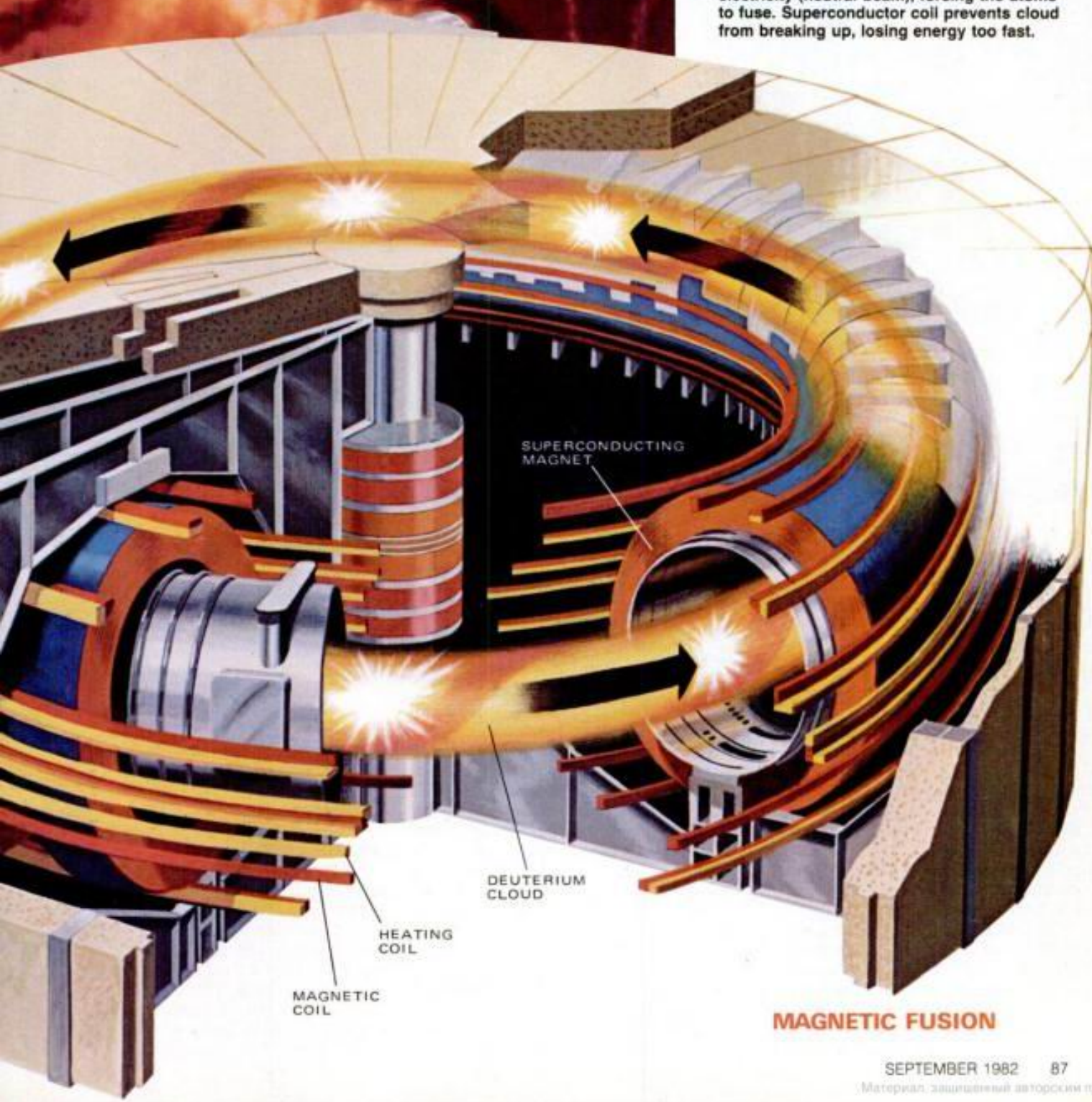
What's more, the whole problem of radioactive waste is avoided. Unlike conventional atomic power plants—which work by *splitting* atoms—fusing atoms produces no "hot" waste. And there's no danger of meltdown or other runaway



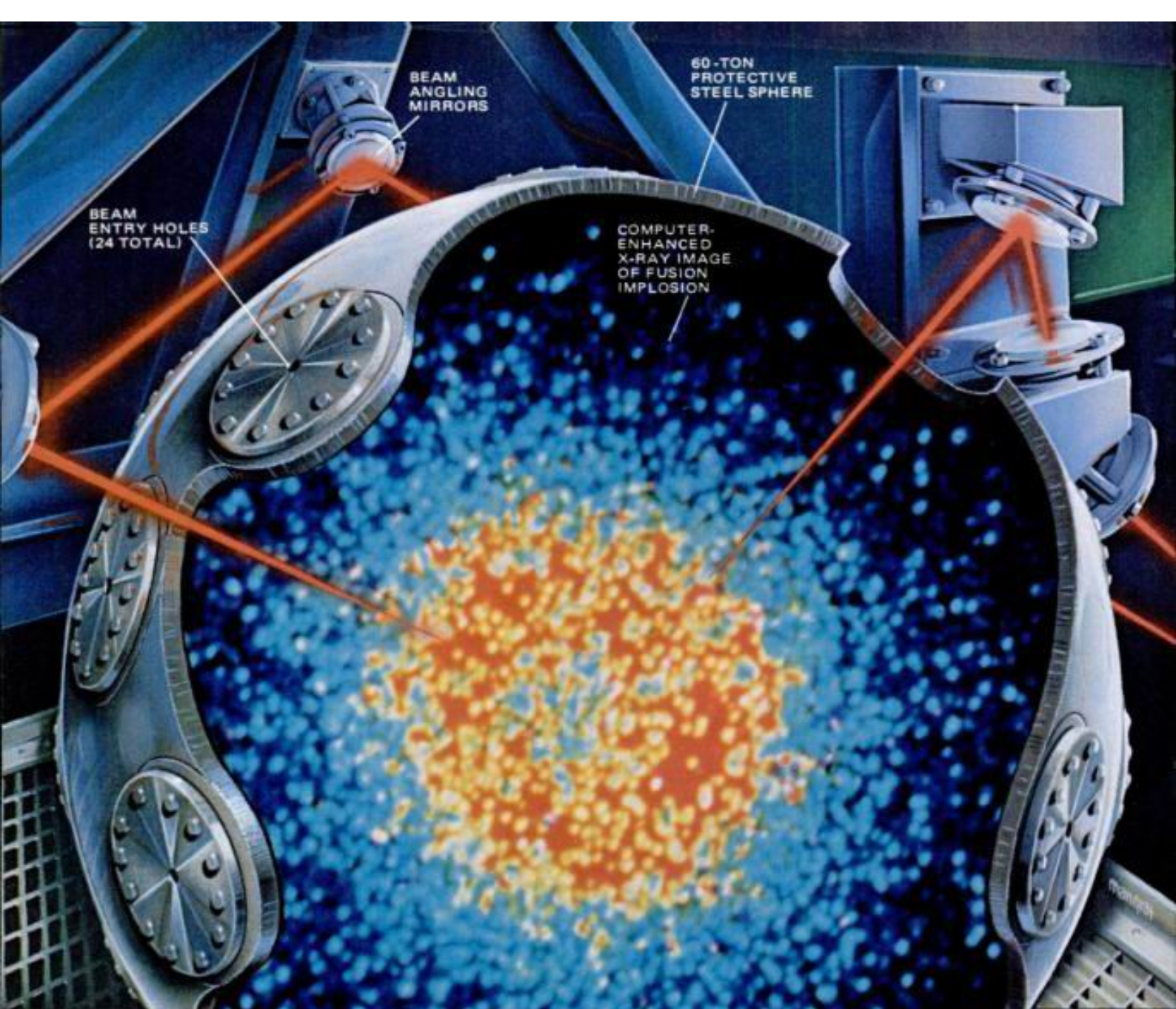
PM art: Dean Ellis



In any fusion reaction, light atoms combine to form heavier atoms, yielding high-speed neutron (above). In Tokamak system (below), deuterium cloud is heated and jolted with electricity (neutral beam), forcing the atoms to fuse. Superconductor coil prevents cloud from breaking up, losing energy too fast.



MAGNETIC FUSION



reactions caused by accident or sabotage. As one technician put it, "Instead of blowing up, it simply fizzles out when something goes wrong."

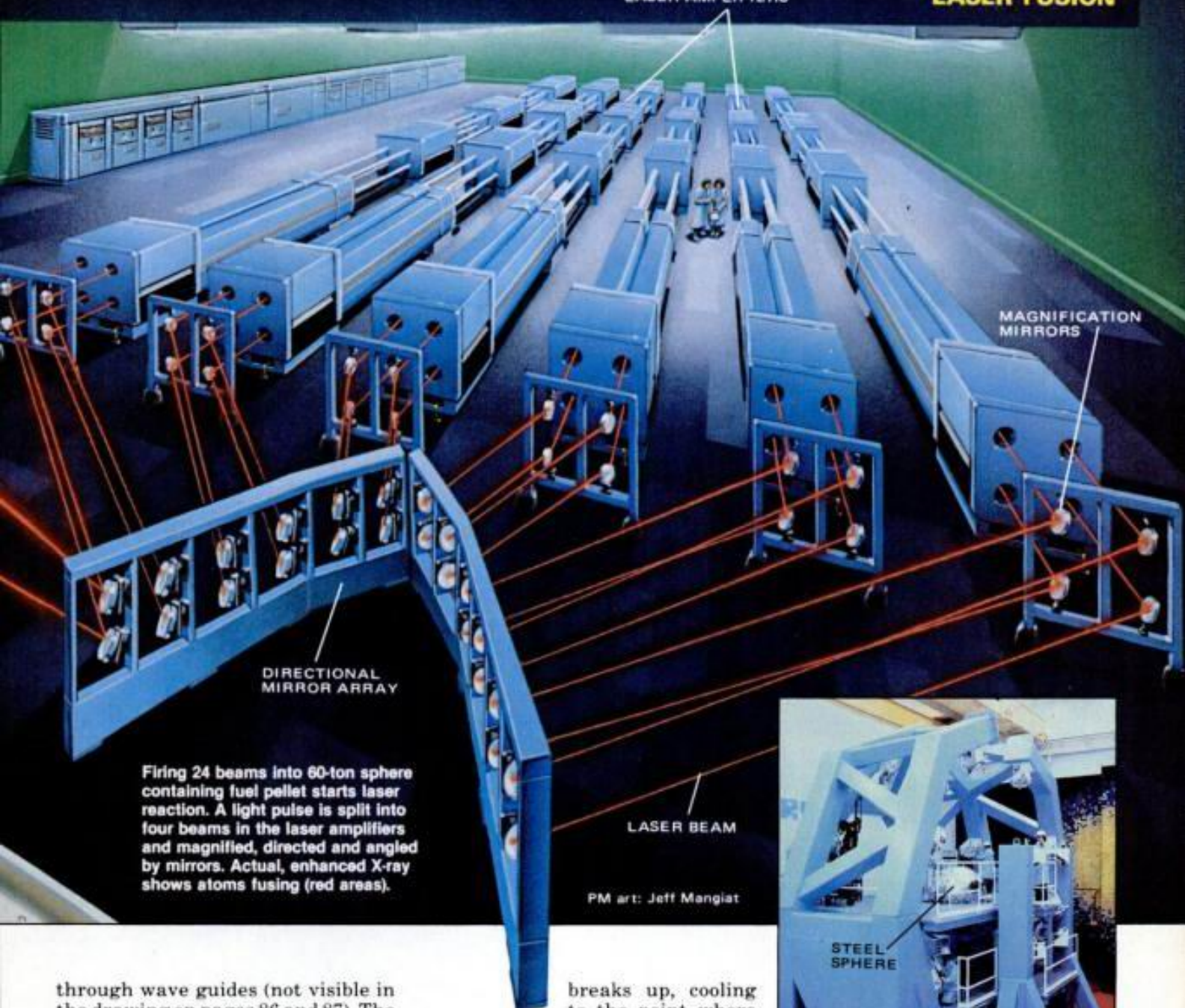
With all these advantages, fusion energy seems to be the answer to many national and worldwide problems. The United States is pouring billions into its development. But though the goal is in sight, tremendous engineering challenges must be overcome before we can all plug ourselves into a fusion-fueled electric power grid.

In the Princeton fusion reactor, deuterium atoms combine with tritium—another plentiful hydrogen isotope. In the process, they create heavy helium atoms and shoot off neutrons at high speeds. This produces vast amounts of energy

that can be used to drive conventional electric power generators. The hitch is that these atoms start fusing only when the temperature gets up to millions of degrees. In fact, the reaction really gets rolling only when temperatures are well over 100 million degrees. That kind of climate is found normally only in the interior of stars like the sun. Thus, in principle, the Tokamak is attempting to create stellar conditions on Earth.

Several ways are being tried. One method jolts the deuterium inside

of the Tokamak with a strong electric current, the neutral beam in the illustration on pages 86 and 87. Since the deuterium is ionized and, therefore, conductive, it acts like a wire in an electric heater and heats up by its own electric resistance. But this doesn't suffice. Additional heat is produced by heating coils and magnetic coils and by magnetic squeezing: A huge superconducting magnetic coil surrounds the reaction chamber, pushing the deuterium toward the center of the tube. This magnetic compression—like any other form of pressure—raises the temperature even further. To pour on still more heat, the ionized mass of deuterium gas is "zapped" with hundreds of kilowatts of high-frequency radio waves sluiced into the reaction chamber



Firing 24 beams into 60-ton sphere containing fuel pellet starts laser reaction. A light pulse is split into four beams in the laser amplifiers and magnified, directed and angled by mirrors. Actual, enhanced X-ray shows atoms fusing (red areas).

PM art: Jeff Mangiat

through wave guides (not visible in the drawing on pages 86 and 87). The principle is similar to cooking in a microwave oven.

Combining all of these heating methods, the latest version of the Tokamak has been able to reach stellar temperatures, trigger a fusion reaction and sustain it long enough to generate significant amounts of power. So far, the big machine has managed to keep this up for about 20 milliseconds. To become an efficient energy producer, it will have to run much longer than that—about 10 seconds or more for each power burst. But keeping the Tokamak going for so long is a very tricky task.

The trouble is that no material on Earth can contain the raging stream of stellar stuff inside the Tokamak. If the swirling deuterium touches the wall of the metal tube containing it, the deuterium cloud

breaks up, cooling to the point where the fusion reaction falters. So the torrent inside the Tokamak must race inside the ring-shaped tube without ever touching its walls. It is, therefore, "contained" in what is called a magnetic bottle—an ultra-strong magnetic field, shaped to hold the deuterium suspended within the doughnut, away from its walls.

Unfortunately, the bottle still leaks. Often, the hot material breaks through the magnetic restraint, cools off instantly and stops the reaction. That's the main reason why the Tokamak is still just a research tool, rather than a working power source.

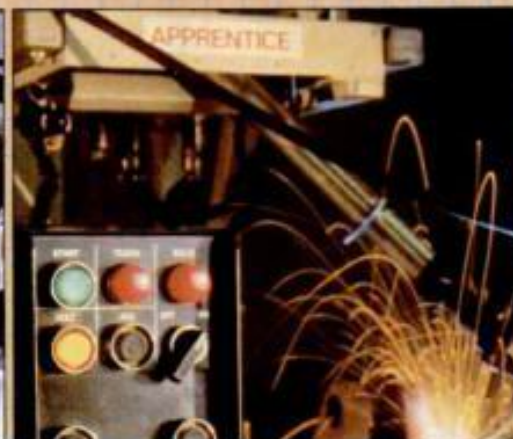
But this may change by the late '80s. A machine almost twice as big as the present Tokamak—called the TFTR, or Tokamak Fusion Test Re-

(Please turn to page 159)



Platform for laser fusion target (above) must be very stable. It contains fusion pellet (below), with its immense energy.





Robots at work: Designing "down" to smaller jobs is illustrated by Unimate robot (left), assembling a TV set; its older relatives learn welding jobs (center) in a matter of minutes, or can simply stack heavy metal parts as they come from the finishing process. Unimation pioneered commercial robotics in the United States, but now has heavy competition.

THE SEEING, FEELING SUPER ROBOT'S TIME HAS COME...

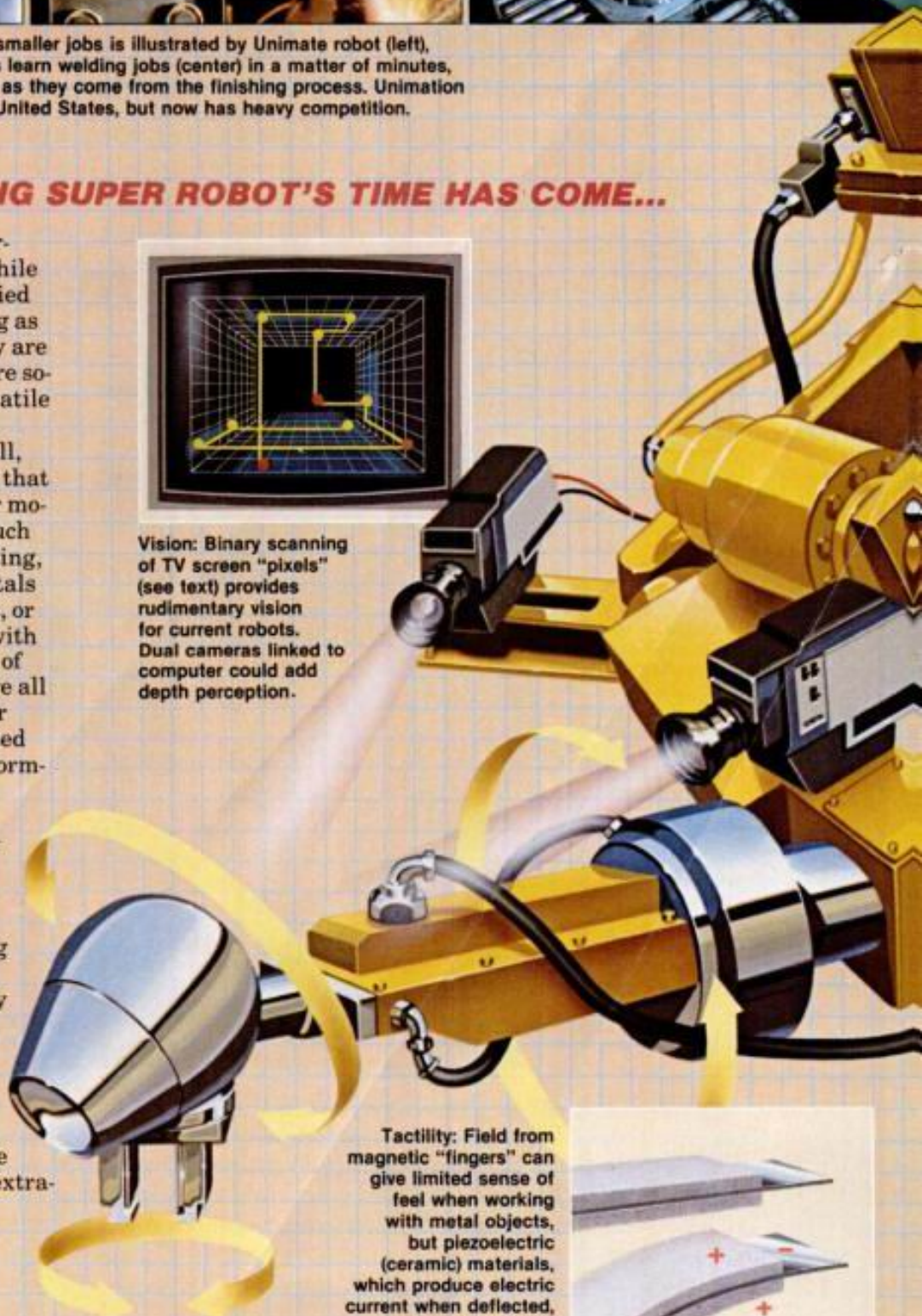
programmable machine that performs some type of work. And while U.S. industrialists originally shied away from investing in anything as "sci-fi" sounding as a robot, they are now clamoring for more and more sophisticated, intelligent and versatile automatons.

What exactly do robots do? Well, they started out doing anything that was considered too dangerous or monotonous for human workers. Such jobs as spot welding and die casting, which involve working with metals at extremely high temperatures, or spray painting in a room filled with toxic fumes, or the transporting of heavy, awkward machinery, were all deemed ideal testing grounds for robotic workers. They have passed the tests with flying colors, performing those jobs with greater consistency, dependability and (eventually) economy than their human counterparts.

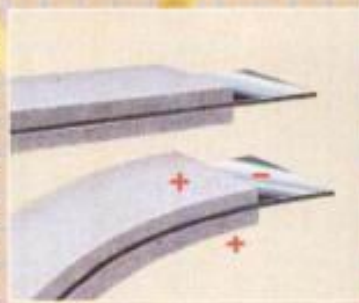
While these tasks demand an artificial intelligence—through computerization—far surpassing anything used in the past, real industrial automatons in no way resemble the popular fictional robots from such films as *Star Wars*. These are machines, not pseudo-people; they will neither pause in their routines for a passing wisecrack, nor take time off to save the Earth from extra-terrestrial threats. Few of today's robots could be said to have anything approaching awareness. All they "know" are the movements that have been programmed into their computer minds; and, in fact, if you happened



Vision: Binary scanning of TV screen "pixels" (see text) provides rudimentary vision for current robots. Dual cameras linked to computer could add depth perception.



Tactility: Field from magnetic "fingers" can give limited sense of feel when working with metal objects, but piezoelectric (ceramic) materials, which produce electric current when deflected, would provide basis for more tactility.





Precision: For critical assembly or processing jobs, conventional gearing doesn't supply consistently accurate robot positioning. Ball-bearing drive system could replace gears in future robots.

Next-generation industrial robot will resemble current systems, but will be enhanced with upgraded precision, vision and tactility. The addition of several axes of motion will also enable it to follow work along an assembly line without slowing normal flow. With accuracy of positioning to the millimeter, three-dimensional vision and tactile feedback enabling it to measure or weigh workpieces—or even to “feel” them—the super robot will be capable of much more complex tasks than is today's generation.

R. Crane

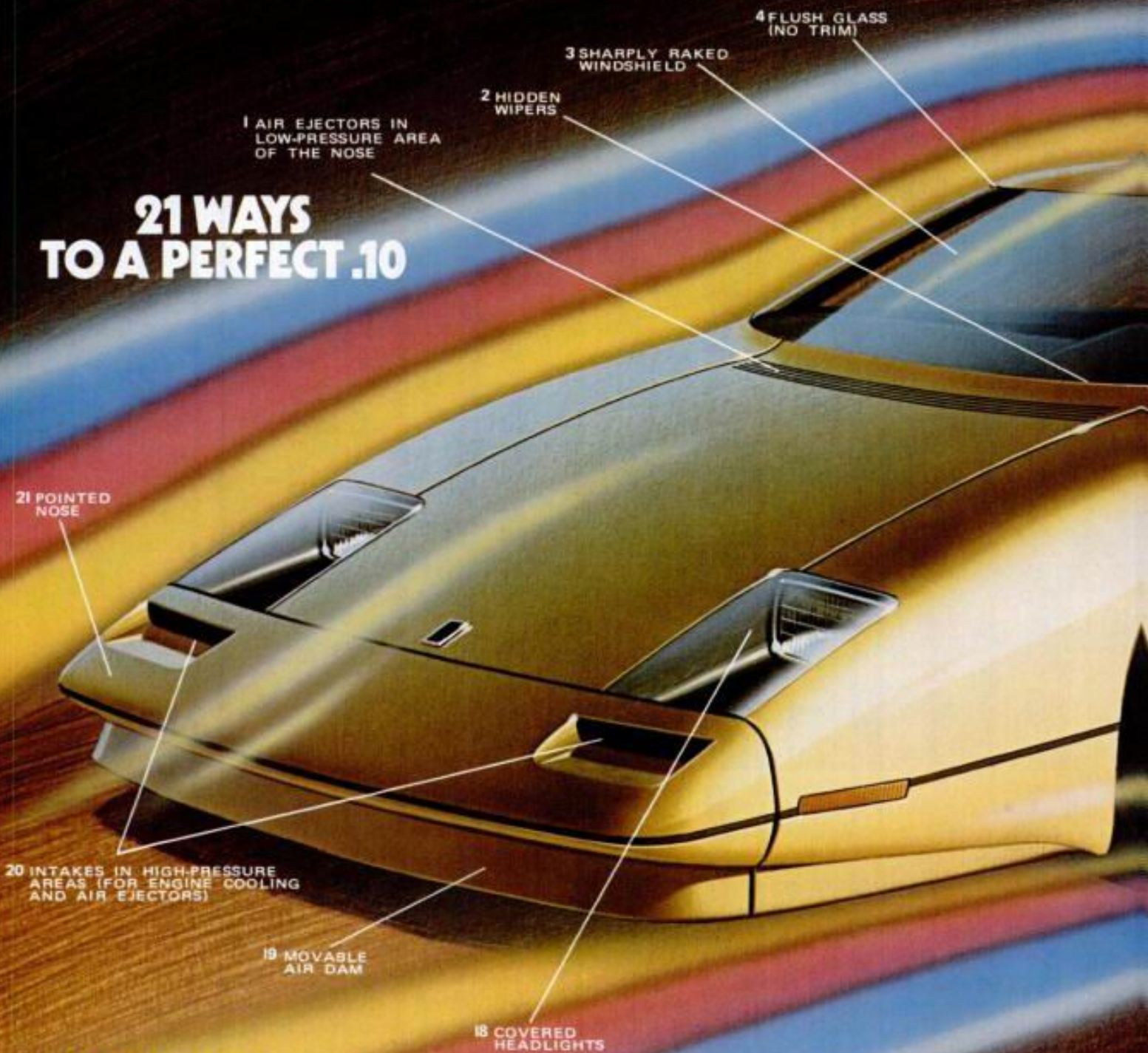


THE SLICKEST THERE IS

This "banana car" is the slipperiest shape yet developed for a passenger car, with a Cd of just .20. It was designed by Prof. Alberto Morelli of Torino Polytechnic University, built and developed by Sergio Pininfarina and financed by the Italian Government.

Morelli came up with his ideas of "zero-lift" body design in the early '60s on the Pininfarina Pf-X and Pf-Y styling studies. This car's main features are a chopped-off Kamm tail, air ejectors in low-pressure areas and a constant-section body. It requires only 7 hp to maintain 60 mph on level ground, for fuel economy at least 30 percent better than a conventional sedan with the same chassis. While this car may seem futuristic and almost unbuildable, Pininfarina claims the shape can be brought into production.—R.T.

21 WAYS TO A PERFECT .10



A car with a perfect Cd of .10 doesn't yet exist. But when it is built, it will probably look very much like this, and incorporate all the aerodynamic tricks that are illustrated here.

PM art: Dale Gustafson

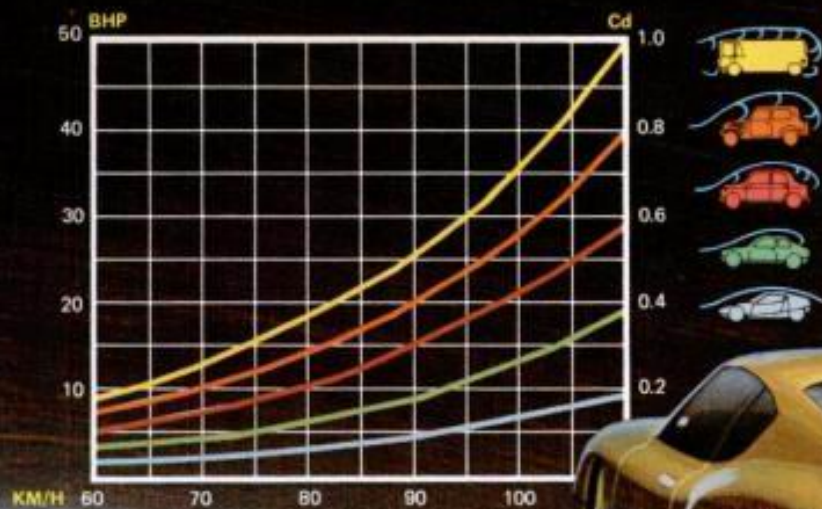
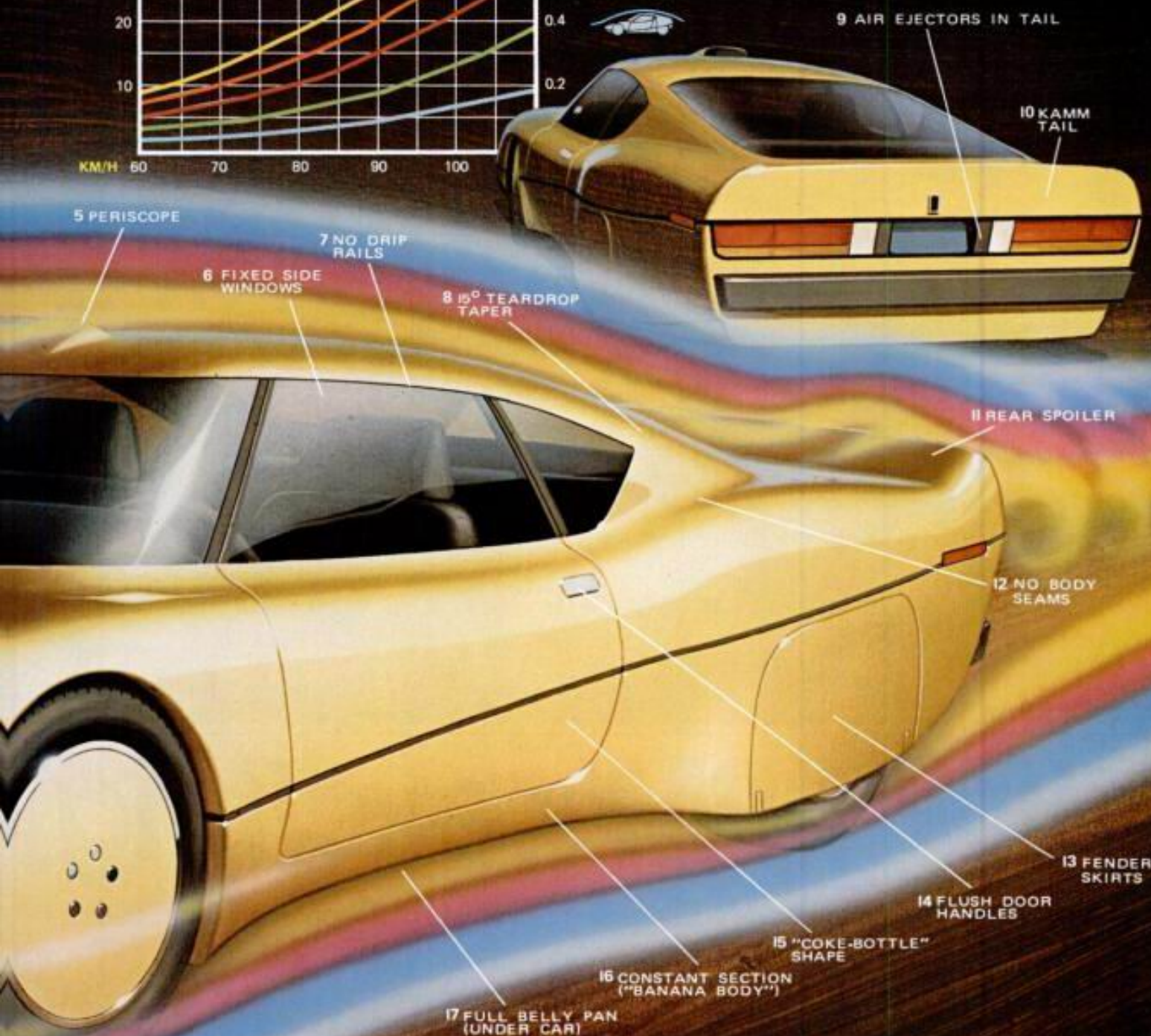


Chart (left) indicates various power needs in brake horsepower (bhp) of aerodynamically different vehicles, all other factors being equal, for speeds from 60 to 110 mph. The coefficient of drag (Cd) ranges from worst possible, 1.0, to nearly ideal, 0.2. Some design concepts in the experimental vehicle (below) are already showing up in production cars.

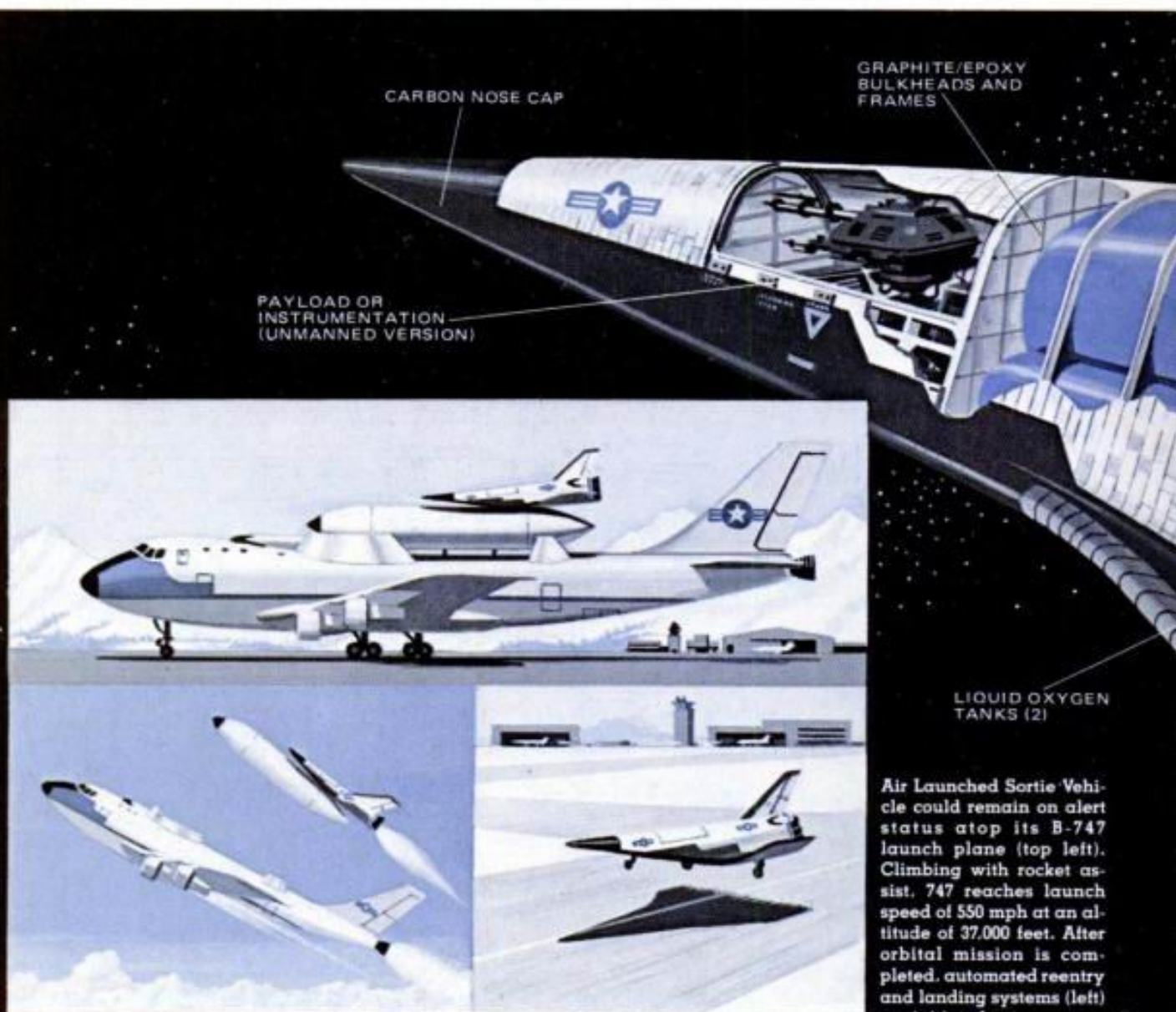


already efficient new engines more efficient.

By playing with a car's aerodynamics, however, a carmaker can achieve a 1- or 1½-mpg gain simply by bending sheet metal and not even touching the engine. And aerodynamic work is much cheaper than engineering a new engine. That 1 mpg can be bought in a wind tunnel for a few thousand dollars, compared with the hundred million dollars it would take to refine a powerplant.

It's estimated that a .06 loss in a car's coefficient of drag (Cd) equals a 1-mpg gain on the road at 55 mph. An example of how cheaply drag can be brought down is the optional decklid spoiler on the new Pontiac J-car, the J-2000. Without the spoiler, Cd was .407. With the spoiler, the Cd went down to .392, a gain of .015. This adds up to a fraction of an mpg gain—not an astounding number, but very cheap, considering the price of a spoiler compared to re-

(Please turn to page 157)



Air Launched Sortie Vehicle could remain on alert status atop its B-747 launch plane (top left). Climbing with rocket assist, 747 reaches launch speed of 550 mph at an altitude of 37,000 feet. After orbital mission is completed, automated reentry and landing systems (left) are initiated.

Aerospace

Piggyback launch for military minishuttle

Ever alert for applications that could lead to orders for its B-747 aircraft, Boeing has concluded that the plane could serve as an airborne launch pad for an orbiting vehicle, employing Space Shuttle technology. The Boeing study, done under an Air Force contract, further concludes that such a spacecraft could fly its initial mission by 1988.

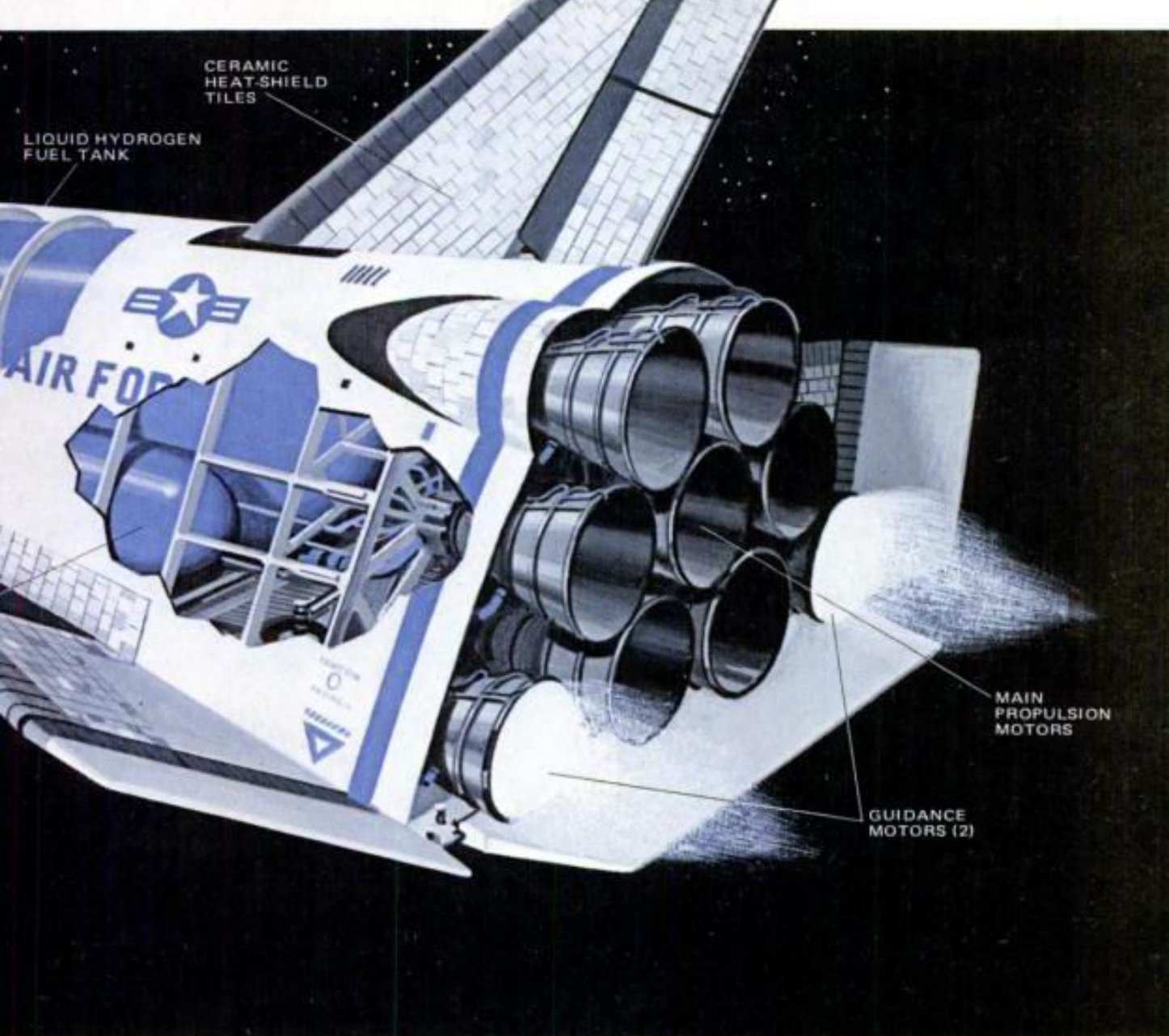
The concept is known as the Air

Launched Sortie Vehicle (ALSV). While much of the design would be derived from the Shuttle's proven systems, there would be differences. The much smaller ALSV could be launched from any military airfield (or commercial airport) capable of accommodating a B-747. It is estimated that the vehicle, placed into a low Earth orbit, could be over any point on the globe within 100 minutes of the launch plane's takeoff. Like the Shuttle, it could be recovered on command; automatic systems in the unmanned ALSV would initiate reentry and landing at predetermined sites.

This seems, at first, to add up to a

global reconnaissance vehicle, instantly available in times of escalating threats to national security. But there is nothing in the concept that rules out a weapons payload, instead of one for surveillance. Thus, the ALSV could become, in effect, an MX missile with the added dimension of retrievability from orbit after it has been fired at an enemy. The mobility of such a system, with a certain number kept on airborne alert, would be a plus. The problems of disarming live nuclear weapons for reentry and possible landing accidents would be its most serious drawback.

However, the system might also be



used to attack and destroy enemy satellites in orbit.

The orbiter would be mated with a single external fuel tank; this 275,000-pound combination would be fixed atop a 747 modified with a launch "ramp," plus fairings and pylons. The other major modification would place a single Shuttle rocket engine, plus liquid hydrogen and oxygen tanks, *inside* the 747.

From either a runway or airborne-alert position, the launch aircraft would climb to about 22,000 feet before lighting off its own rocket engine. As thrust develops, the 747 would climb rapidly to near 40,000 feet at a nose-up angle of approxi-

mately 60°. At this point, at a speed of about 550 mph, the ALSV and its fuel tank separate from the 747. The airliner pushes away from the orbiter as two guidance engines are fired to stabilize it and provide more separation. Then all nine modified RL-10 liquid hydrogen/oxygen engines ignite, boosting the ALSV toward orbit. These engines consume all the fuel in the external tank to provide orbital velocity; the tank is jettisoned and burns up in the upper atmosphere.

The remaining fuel on board the ALSV is sufficient for maneuvering and reentry. Although initially proposed as unmanned, the vehicle could be modified to carry a crew,

further enhancing its surveillance and antisatellite capabilities. A manned version could proceed against electronic defenses without requiring jammable command inputs to be relayed from ground stations or friendly satellites.

No doubt, other applications could be found for an operational orbiter with a 100-minute, rendezvous-anywhere capability. An empty version with limited life-support capabilities, for example, might simply stand by during manned orbital missions for possible use as a space "lifeboat."

Editor: Robin Nelson

NASA's hopes rest on high technology

COMPUTERS

Five identical on-board computers are essential for navigation and control of the shuttle. Array is far more powerful than data-processing gear aboard any previous spacecraft, with three times the memory capacity and 40 times faster processing than computers aboard Saturn V vehicles. A concern: Computers must be cooled adequately to work.

DOOR HARDWARE

Payload bay doors must open in space to expose heat-dissipating radiators. And 32 latches must be closed before reentry to prevent heat buildup in bay, which could threaten the structural integrity of the orbiter's midsection.

TILES

Much-publicized tiles protect aluminum skin from 1000° Celsius (1832° F.) temperatures during reentry. But tiles are at greatest risk during liftoff and as spacecraft approaches Mach 1 at around 30,000 feet, about a minute after leaving pad. Major concerns: buffeting noise (about 160 decibels) at liftoff and mechanical stress near sound barrier.

COOLING SYSTEMS

Radiators (which in an actual mission would not be exposed until engines are shut down) consist of rows of aluminum pipe, with a total length of close to a mile. Liquid Freon flowing through pipe transports heat from avionics and crew for release into space. Flash evaporators, behind cargo bay, also dispose of dangerous heat by using it to boil water. The resulting steam is then vented overboard.

EXTERNAL TANK

Expendable, comparatively inexpensive fuel tank holds entire shuttle structure together at launch. One critical feature: Cork/epoxy coating and spray-on foam insulate cold fuel containers from outside air, preventing a buildup of ice that could endanger the orbiter if the ice breaks off in chunks at liftoff.

LIQUID OXYGEN

LIQUID HYDROGEN

Shuttle engineers pinpointed key systems for PM. The risk and challenge: Much of the vital hardware has never flown in space before.



ORBITAL MANEUVERING ENGINES

Two engines to left and right of upper main engine begin firing after main engines are throttled down, boosting spacecraft into orbiting speed of about 17,500 mph. Each fires with up to 6,000 pounds of thrust. Near the end of a mission, these engines supply energy to pull out of orbit and return to Earth.

MAIN ENGINES

The challenge was pulling more power from a smaller-sized engine that could be reused in dozens of missions without major overhaul. In tests, the three 14-foot-long main engines delivered the highest thrust per weight of any engine ever made. Each is to put out 188,000 tons of thrust at launch, the equivalent of 6.5-million hp.

THRUSTERS

Reaction-control thrusters in nose and rear provide vital control of attitude during re-entry. The 44 small rockets, each with its own fuel tank, also fine-tune velocity for rendezvous and docking—critical maneuvers in future missions.

BOOSTER ROCKETS

Two solid-fuel booster rockets, largest (150 feet long) ever flown and the first designed for reuse, lift shuttle to about 30 miles before dropping away for ocean recovery. They will be ignited shortly after three main engines fire, developing more than 5 million pounds of thrust. Second critical time: Thrust is to drop off a minute into flight to avoid overstressing vehicle as it nears speed of sound.

MAIN PARACHUTES

PM art: Dale Gustafson

A generation of manned space

MERCURY REDSTONE 3 May 5, 1961

The orbital flight of Russian Yuri Gagarin on April 12 helped assure nervous U.S. scientists that man could survive weightlessness. But some senators argued the planned quarter-hour suborbital Mercury flight should be conducted in secret in case it failed. And President John F. Kennedy kept calling NASA for further reassurances of safety almost until launch. Navy Cmdr. Alan B. Shepard went through almost a minute of buffeting after liftoff, then entered weightlessness without realizing it. "Just a pleasant ride," he said after dropping into the sea.

GEMINI 4 June 3-7, 1965

Astronaut Edward H. White floated out of the cramped two-man capsule and into space over Hawaii during the third revolution around the Earth. "I was reluctant to come in," White said later. His 23 minutes on the end of a tether disproved contentions that men would experience an overwhelming dizziness outside of their spacecraft. But the flight was not without a hitch: A computer failure required White and James A. McDivitt to take over manual control during the landing, and the capsule dropped about 50 miles short of its target.

APOLLO 11 July 16-24, 1969

In dazzling sunshine, at 10:56 p.m. EDT on July 20, astronaut Neil A. Armstrong pulled a "D" ring to aim a TV camera at the gray lunar surface. Then he stepped into the picture—onto the moon. He and Edwin "Buzz" Aldrin reported little difficulty exploring the hostile land, where temperatures outside their suits varied from 180° F. in the sun to -160° in the shade. Researchers had suggested a "kangaroo lope" to help them move, but the astronauts found that the old left-right earthly shuffle worked fine.

President Kennedy fretted over the first Mercury flight. A few years later, scientists feared that astronauts would suffer vertigo if they climbed out of their vehicles in space. A few years after that, some argued man would never really walk on the moon, but would have to lope like a kangaroo. Each successful shot killed some myths and constructed a step to the next flight—and new fears.



flight: Some NASA highlights

SKYLAB 2 May 25-June 22, 1973

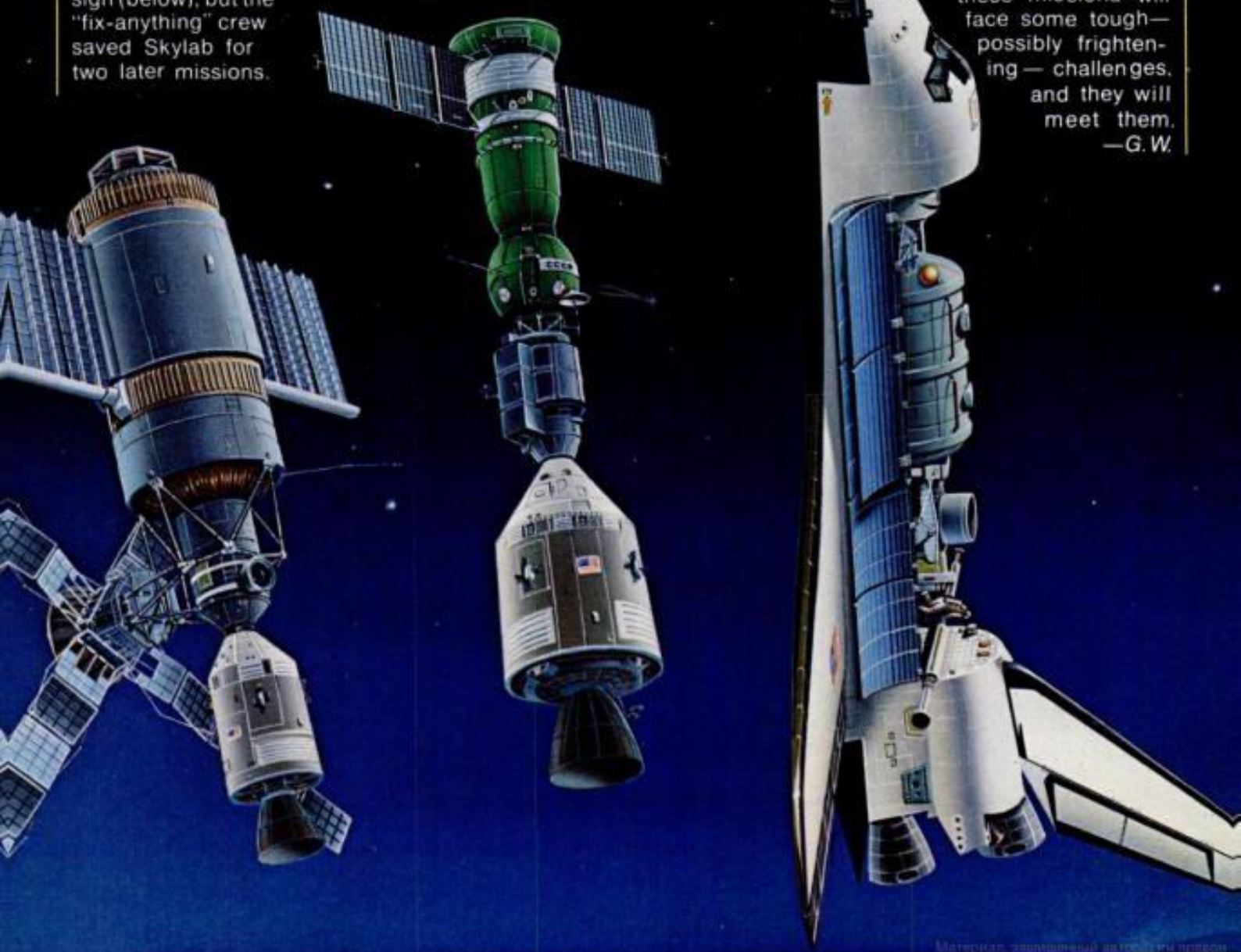
Skylab's problems began about a minute after its unmanned launch when an 800-pound meteoroid shield was torn from the canister-like orbital workshop, ripping away one solar-power wing and jamming the other. The first Skylab crew, Charles Conrad Jr., Paul J. Weitz and Joseph P. Kerwin, went to work as soon as their modified Apollo spacecraft had ferried them to the damaged ship. They erected a sun screen over the workshop to replace the missing shield. Then they freed the jammed solar panel and repaired broken-down instruments. Some of the repairs were seat-of-the-pants: Conrad fixed a battery by hitting it. Skylab never recovered the symmetry of the original design (below), but the "fix-anything" crew saved Skylab for two later missions.

APOLLO SOYUZ TEST PROJECT July 15-24, 1975

"Tovarich! [Friend!]" called Apollo Commander Tom Stafford as a hatchway cleared to reveal two smiling Russians. The Soyuz skipper, Aleksei Leonov, replied "Very, very happy to see you. How are things?" The meeting of five men in space after Russian and American spacecraft had docked occurred about 140 miles over Amsterdam. Detente was still alive. Russian headlines celebrated an "Orbit of Cooperation," and Stafford forced down three tubes of borscht. After the hoopla, the reentry of the American crew was a reminder of space-travel risks: Human error led to firing of thruster rockets in the air. Their exhaust made the crew choke, but did no permanent damage.

SPACELAB 1983 and beyond

Up to four men and women will be able to work in Spacelab, the comparatively commodious orbiting laboratory held in the cargo bay of the shuttle orbiter. In a shirt-sleeve environment, international teams of scientists will carry out experiments in a weightless facility equipped with microscopes, centrifuges, incubators, materials-processing furnaces and other gear. Scientists themselves need not be astronauts; some will take off after just a few weeks of instruction. Farther in the future: free-floating Spacelabs, a step toward internationally manned space stations. If previous benchmark space shots are an indication, pioneering crews on these missions will face some tough—possibly frightening—challenges, and they will meet them.
—G.W.





PROPPING UP



Nacelle's faired end faces the wind as it swivels 260 feet above the ground.

FIBERGLASS
ROTOR

LOW-SPEED
SHAFT ASSEMBLY

HYDRAULIC
ACTUATOR

ROTOR BRAKE AND
LOCK ASSEMBLY

SPRING-CONTROL
DAMPS SWIVEL

SLIP RINGS (NOT VISIBLE)
TRANSFER GENERATOR
CURRENT

A MONSTER

An old-line airplane propeller company outdoes itself in engineering the biggest and most powerful windmill on earth—or in the air.

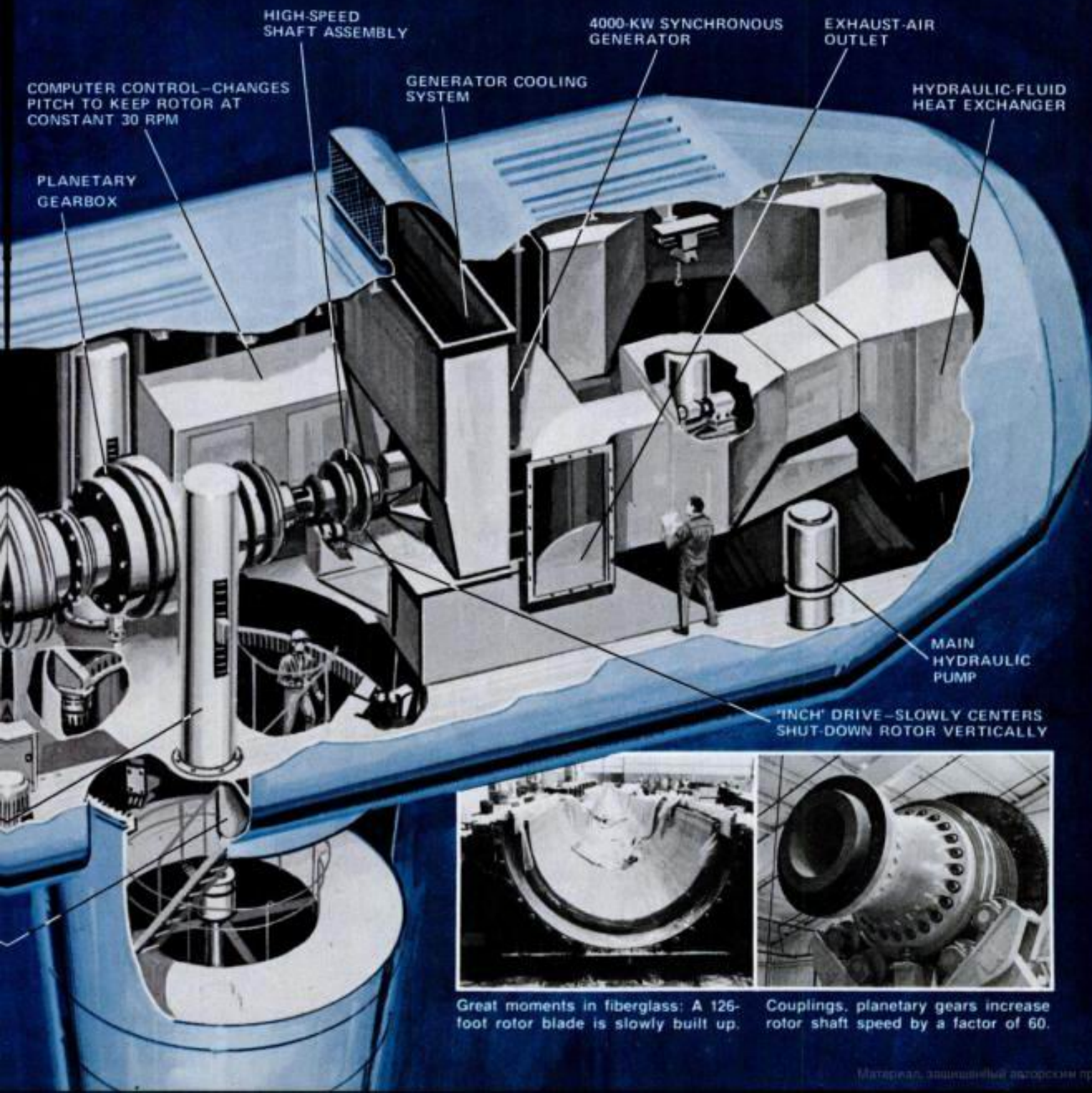
by Mort Schultz

The world's largest "propeller"—257 feet from tip to tip—is being readied by Hamilton Standard (now a division of United Technologies), the same company that built the prop for Lindbergh's *Spirit of St. Louis*.

Appropriately, the giant blades will twirl about the business end of the world's largest windmill. It's no pie-in-the-sky scheme on some drawing board, either. Installation of the giant system at Medicine Bow, Wyo., under the aegis of the Department of the Interior, will be

underway by October. Once it is whirling in the winds (which more than half the time average over 33 mph—the point at which the generator reaches rated power), above Medicine Bow, the unit is expected to supply about twice as much electrical power as the current world's largest windmill, the government's experimental system in Boone, N.C.

If it proves out, the projected next phase would be the installation of multiple units of the same design—an entire Wyoming "farm" of mammoth wind machines. **PM**



Great moments in fiberglass: A 126-foot rotor blade is slowly built up.

Couplings, planetary gears increase rotor shaft speed by a factor of 60.

RARE BIRD



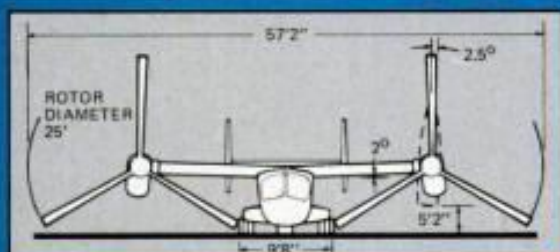
ROTOR TIP SPEED
AT HOVER: 740 F.P.S.

CONVERSION
ACTUATOR

CONTROL-PHASING
ACTUATOR

WINGSPAN: 34.6 FT.
AREA: 181 SQ. FT.

CONVERSION
INTERCONNECT
SHAFT



Rotors' 25-foot diameters preclude airplane-type landings. Nacelles must tilt up to the 60° position.

Is it the world's fastest rotorcraft or just the most versatile airplane? Either way, it works.

Advanced concepts in aerodynamics do not leap into the air overnight. Bell Helicopter (Textron Corp.) engineers have been flight-testing aircraft incorporating the "tilt-rotor" powerplant/wing format for the better part of three decades. With the XV-15, however, the idea appears to be hitting its stride at last. This aircraft achieved a speed of 301 knots (346 mph) last June, breaking an unofficial record for rotorcraft. The two extant models of the experimental craft are being tested by NASA and the military this year. Practical designs that evolve after this testing phase could have a

wide range of both civil and military applications.

Inflight operation of the unique aircraft is apparently far less hairy than it seems at first glance. Takeoffs can be made from a hover (in ground effect) to clear a 50-foot object in about 450 feet. Normal takeoff mode, however, has the nacelles set at 60° for a ground roll of about 950 feet, with 50-foot clearance in 1,440 feet. Once aloft, with 45 knots or more of airspeed, the pilot can "convert" to airplane-type flight in as little as 12 seconds.

Since the twin rotors are cross-coupled by a shaft through the wing, single-engine flight operation proceeds normally with reduced performance. In the event of total power failure, the nacelles are "reconverted"—it can even be done manually, like cranking down landing gear, in the absence of

DOES IT ALL



hydraulic pressure—to a position that, at 95°, is slightly "backward" and allows an auto-rotation descent to an emergency landing with a final approach speed of about 50 knots. In the same emergency mode, the wings support a glide ratio of 10:1.

The relatively slow turning of the rotor blades—about 560 rpm in helicopter mode; some 100 less in airplane flight—makes for quiet operation with two Lycoming turbine engines that produce 2,800 hp together. Bell engineers say the XV-15 can fly over an urban area at 1,000 feet without being noticed—a feature that definitely enhances the future of tilt-rotor designs.

But it is the speed/economy advantage over conventional choppers that looms foremost in the tilt-rotor's favor. **PM**



Flight transition can be accomplished in 12 seconds; the pilot has a 70-knot "envelope" for the intermediate positions.



QUANTUM WAR: BEAM WEAPONS IN ORBIT!

Scenarios built upon the eerie, soundless violence of combat in space are no longer found exclusively in science fiction. In the '80s, we are printing them in the defense budget. Artist Paul Alexander's version here, of course, far outleaps current technology, but the basic elements are evolved from what is well known. ICBMs near the end of boost phase are being destroyed by orbit-

ing, directed-energy artillery units. Some missiles seem to fly on undamaged, but their guidance systems have been permanently disabled by huge jolts of energy delivered deep within the functional core.

Winglike panels contain some synthetic solar cells to supplement the reactor-powered electrical system of the beam weapon. But a major function of the array is to trap hydrogen ions from the solar



wind—these are the “bullets” with which the system reloads itself. Accelerated to nearly the speed of light in an electrical field along the barrel, the hydrogen ions are stripped of an electron—neutralized—as they depart. (In space, charged particles such as protons and electrons would scatter harmlessly due to mutual repulsion.) AWACS-type radar provides target data.—R.N.

PM art. Paul Alexander



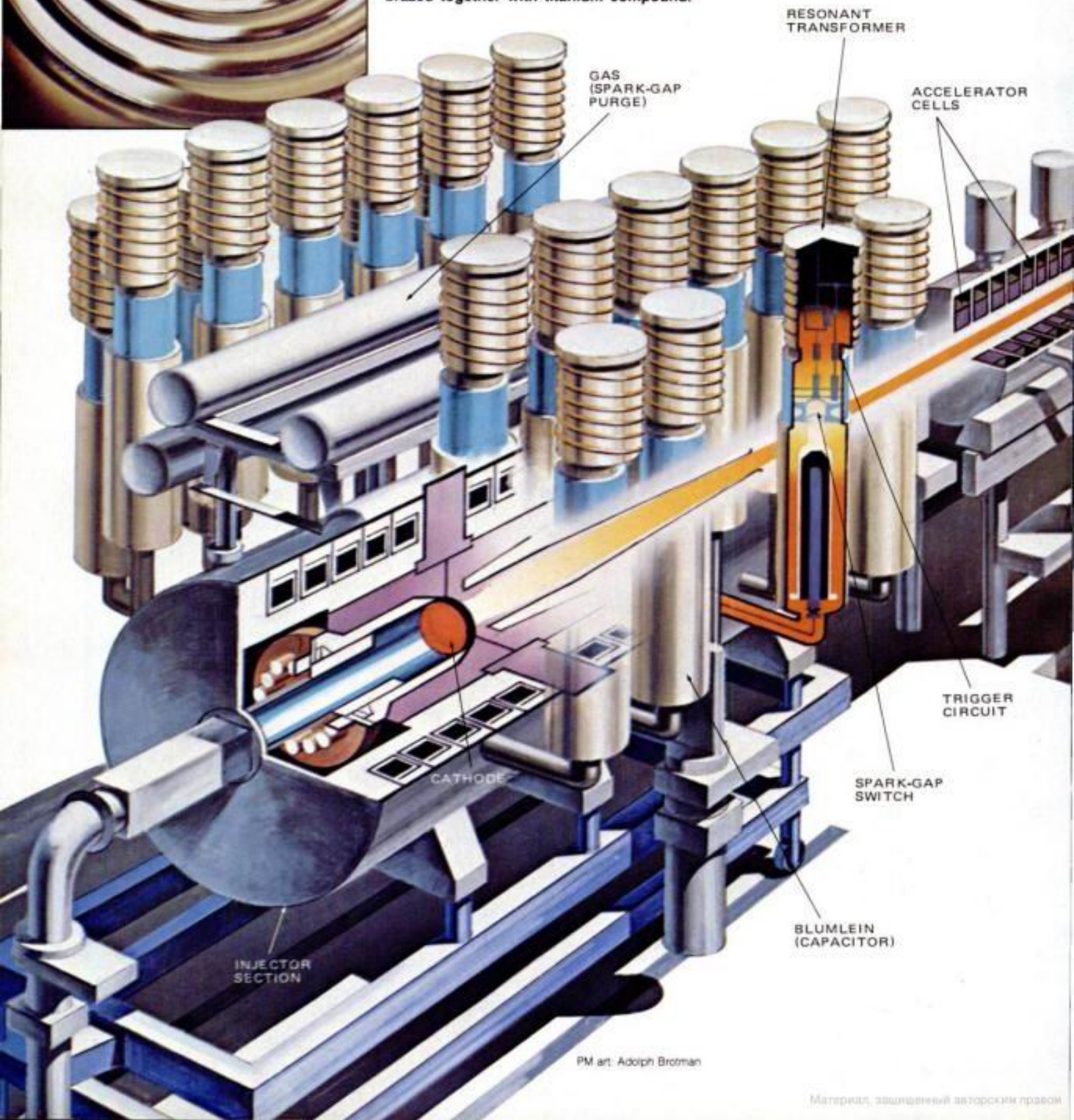
significant mass. But the actual speed of light is involved only as a limiting factor, by which Einstein predicted the total energy available in the destruction of matter—as in a nuclear reaction. The kinetic energy of any moving object, from a dandelion tuft to a falling safe, can be found by taking its mass times the square of its velocity.

This is why military technologists can get excited about a machine that

will accelerate the lightest discrete particle ever weighed—an electron—up to .999 times the speed of light. Electrons exiting this accelerator will effectively weigh 100 times more than they did on entry, 500 feet back in the system.

These numbers, however, tell only part of the story, since the behavior of the electrons upon contacting a target is what counts. The mass acquired in the accelerator is imme-

Outer shell of an accelerator cell is an airtight cylinder of copper and porcelain rings brazed together with titanium compound.

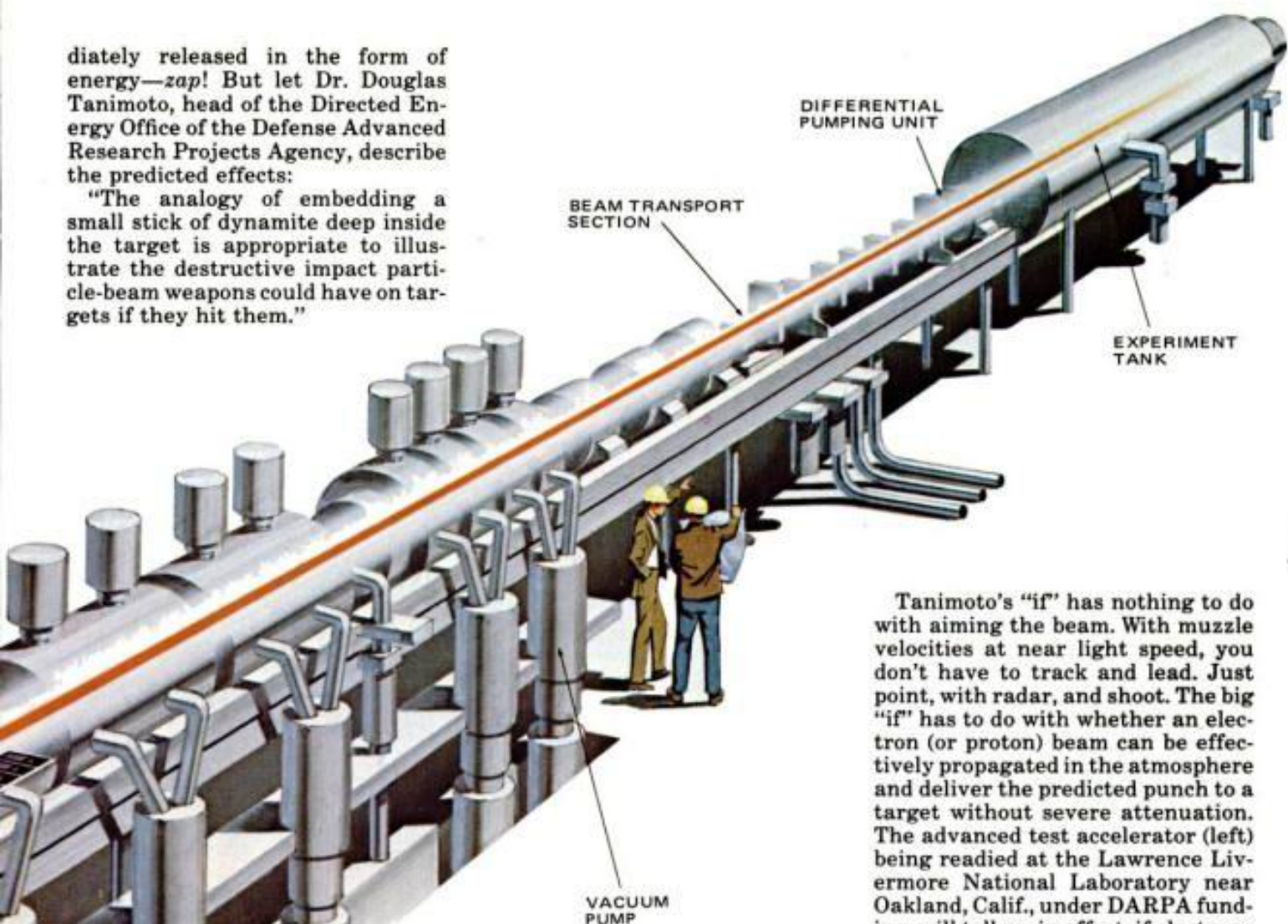


PM art: Adolph Brotman

Материал, защищенный авторским правом

diately released in the form of energy—zap! But let Dr. Douglas Tanimoto, head of the Directed Energy Office of the Defense Advanced Research Projects Agency, describe the predicted effects:

"The analogy of embedding a small stick of dynamite deep inside the target is appropriate to illustrate the destructive impact particle-beam weapons could have on targets if they hit them."



Tanimoto's "if" has nothing to do with aiming the beam. With muzzle velocities at near light speed, you don't have to track and lead. Just point, with radar, and shoot. The big "if" has to do with whether an electron (or proton) beam can be effectively propagated in the atmosphere and deliver the predicted punch to a target without severe attenuation. The advanced test accelerator (left) being readied at the Lawrence Livermore National Laboratory near Oakland, Calif., under DARPA funding, will tell us, in effect, if electrons are any good as bullets.

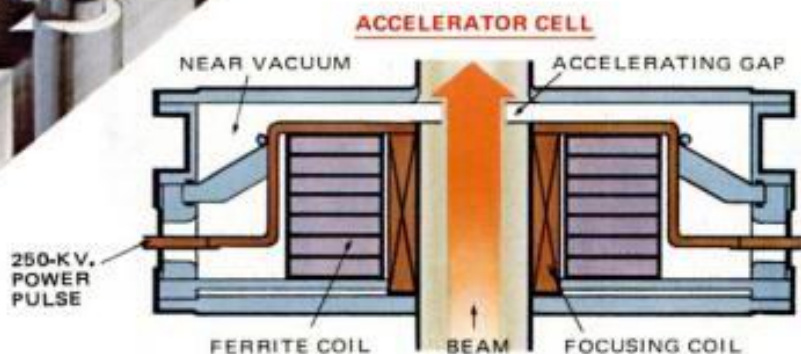
Up to now, particle-beam development has been a very small part of directed-energy weapons research.

Almost \$2 billion has been spent on high-energy laser research, and this continues at the rate of \$200 million per year. Yet even a working laser weapon could be thwarted by rotating targets at high speed, or ablative-type shielding. A laser has to chew its way from outside in. But in the case of a particle beam, "deep deposition of the energetic particles in the target," as Dr. Tanimoto points out, "provides a very high probability of catastrophic kill and makes shielding very difficult."

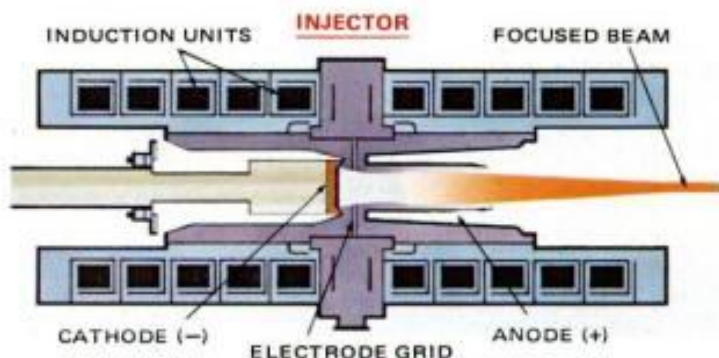
Soviets have the jump

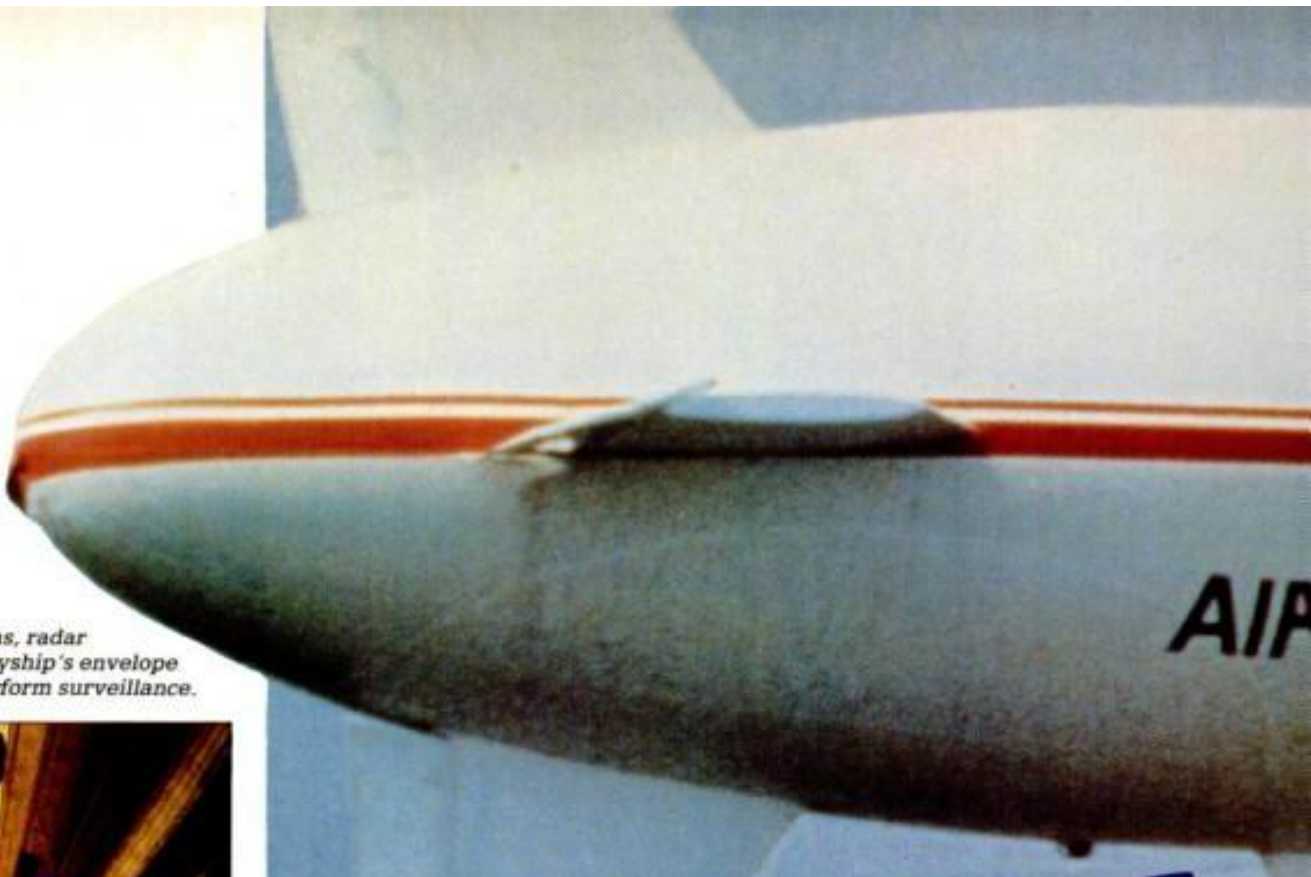
Another reason particle-beam development will get more attention is that the Soviet Union is believed to be well ahead in testing weapons-grade beam technology. A facility has been identified near the Sino-Soviet border which apparently has an array of explosive-flux (Pavlovski) generators of the type associated with pulse-power for beam accelerator work. These relatively light units use explosives to collapse conductors around a strong magnetic

(Please turn to page 141)



Cathode (below) is a hot metal plate releasing electrons into an electric field; cone-shaped anode begins to form beam. Accelerator cell (above) uses timed power pulses to magnetically speed up electron beam and compress it as it passes.





For spy missions, radar boom inside Skyship's envelope (below) can perform surveillance.



The support rigging (above) for Skyship's gondola is of Kevlar cable attached to load curtains.

Airships Rise Again!

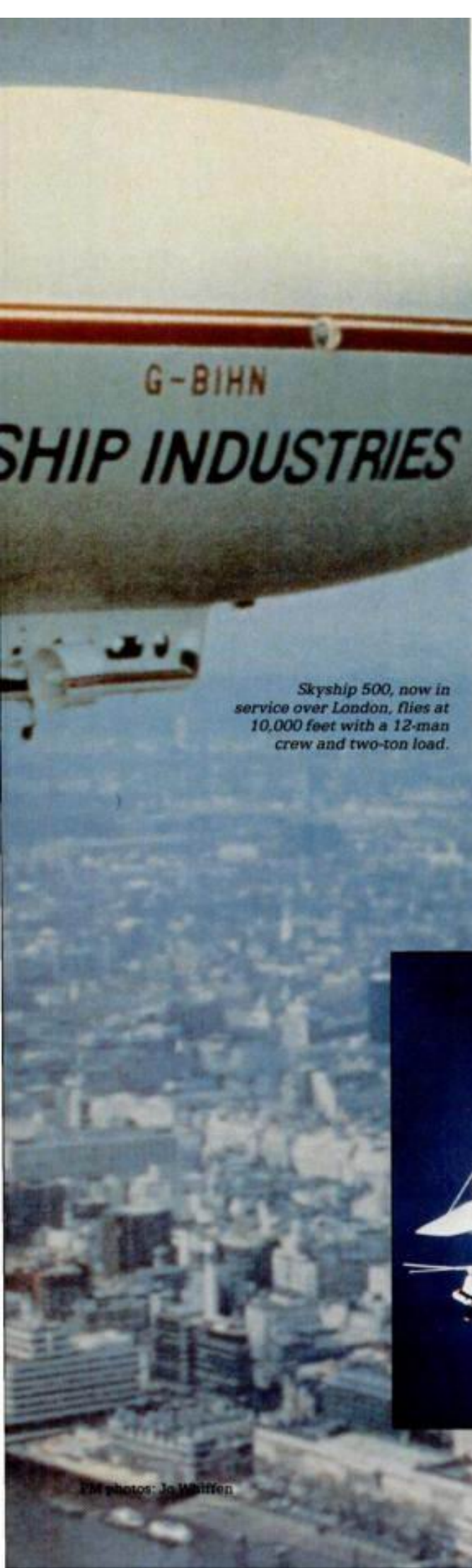
They float along ponderously, seeming relics of the past. But airships are making a comeback!

BY MIKE STOWERS

Flying Golfball: The Airship Inspired By PM

It's often described as a flying manta ray carrying a basketball on its back. But maybe giant golfball would be a better word for the experimental heavy-lifter LTA 20-1. One of its designers, Frederick D. Ferguson, says the 20-foot-high airship was inspired in part by a PM article on the aerodynamics of a golfball (see *Golf's Secret Weapons*, page 78, Dec. '78). The craft's balloon, currently being scaled up to a diameter of 160 feet by Van Dusen Commercial Development of Canada, gets lift in three ways: from helium, from rotating fan engines and from the Magnus effect. To take advantage of the Magnus effect, the LTA 20-1 rotates on pins that connect the balloon to the tips of the manta ray's wings. A boundary layer of air forms around the smooth balloon, giving the whole craft enormous lift.—D.E.





Skyship 500, now in service over London, flies at 10,000 feet with a 12-man crew and two-ton load.

On a chilly day last fall, a British Royal Air Force squadron went into alert status to investigate a flying object visible for miles with the naked eye, but which made only a very faint blip on radar screens. The massive object chugged along beneath the cloud cover, gliding right into the approach pattern generally used by the Royal family returning to London from trips to Balmoral Castle in Scotland. To the surprise—and relief—of just about everyone, the UFO turned out to be a friendly dirigible—an Airship 500 making a test run for Airship Industries.

"There's no metal in the structure," explains Reg Hillsdon, Airship's North American representative. "It's all plastics and composites. They stay well-hidden from radar."

Silent running is just one major feature bringing airships back on the scene. Various design configurations make helium-filled vessels front-runners for some futuristic assignments. Hauling lumber or other heavy loads, even taking the place of military spy satellites at less than one-hundredth the cost are among the possibilities. In the very near future, airships are expected to carry passengers around the 2,000 islands off Greece. There are airports on only a few of the islands so airships, which can land on very small and rough fields, will be competitive with airplanes. Airship Industries has sold three vessels to an Aegean touring company.

Airships have been out of the luxury passenger business for the most part since the German rigid vessel *Hindenburg* crashed in flames in Lakehurst, N.J., 46 years ago next month, killing 21 people. That tragedy and several military accidents helped end the much-heralded flying machines' popularity.

But the ships plying the skies today are far safer than even the safest airships of the past. (Incidentally, air-



Goodyear, whose famous blimps are the only airships that are currently operating in the United States, has prepared this concept for a heavy-lifter.

Airships Rise Again!

ships had almost three accident-free decades at the turn of the century, but this fact is overshadowed by a few spectacular accidents.)

The new vehicles are filled with non-combustible helium instead of volatile hydrogen. And latest-generation plastics give the new airships the structural toughness of old-time rigid ships with the lightness of nonrigid vessels. The Skyship 500 in the middle of last fall's royal scramble carried two tons of load and a crew of 12 in its gondola. It moved around almost noiselessly, powered by two 200-hp Porsche engines at speeds up to 60 knots, and soared above 10,000 feet with a full load.

In a Toronto hangar, an Airship team is in the midst of assembling a Skyship 500 for testing later this year by the U.S. Navy. The dirigible will take about one week to meander along the Atlantic coast to Weeksville, N.C., where Navy pilots will be trained to fly it. Then the Navy plans to test the vessel as a radar platform, a sonobuoy-dragger for submarine hunting and a fleet escort vessel.

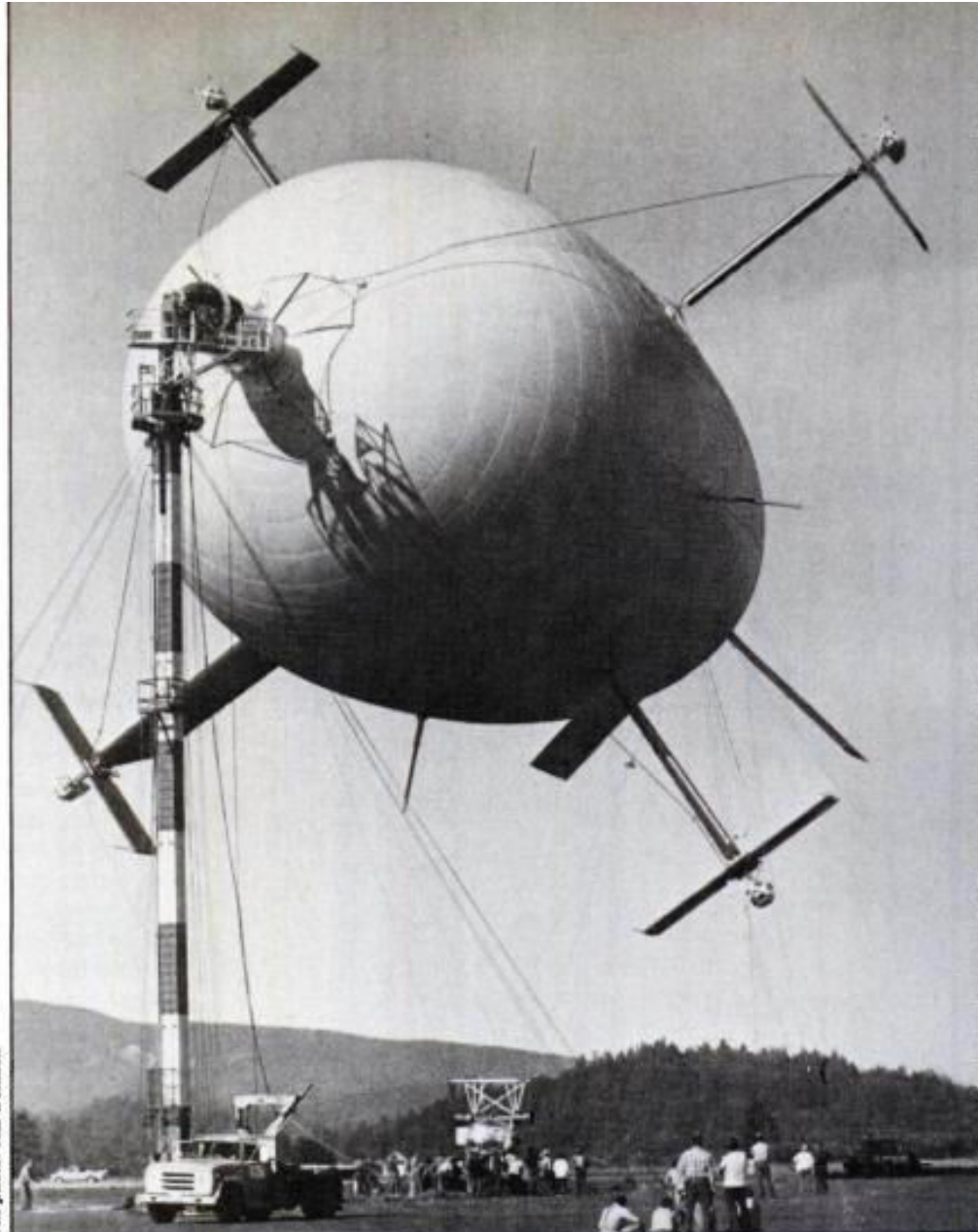
Even while the Navy puts the skyship through its paces, the Forest Service



The large hangar space required by airships, such as those built for the Goodyear blimps (above) have discouraged potential airship users. Still, the airships are excellent candidates for flying radar platforms. Goodyear has added experimental radar to the *Enterprise* (right).



PM photo: Hal Denison



The Cyclo-Crane (above), its helicopter engines operating, and its nose cockpit instrumented, was flight-ready shortly before a storm dashed it against its moorings.

will be testing engines for a heavy-lifter called the Heli-Stat (photos on facing page) being developed by Piasecki Aircraft Corp. at Lakehurst. The lifter, still under construction at press time, is similar to one that crashed in a freak accident two days before its first scheduled test flight in Oregon last year. It also resembles a lifter still on the drawing boards at Goodyear Aerospace.

All of the lifters place helicopters or helicopter-like rotors at four corners of

a light frame that hangs under the airship. The propellers give the airship extra lift and greater ground speed as they haul tons of lumber or other heavy cargo. Goodyear's concept would use a 2.5-million-cu.-ft. nonrigid airship as its basic lifter. The Piasecki craft under construction uses 1.1 million cu. ft. of helium to lift a maximum 37 tons.

Lifter destroyed

So far, the only heavy lifter ever completed was destroyed in a storm at its moorings in Tillamook, Ore. "The crew went home for the night and a storm blew up," says Hal Denison, who has photographed the Aero Lift Co.'s vehicle extensively. "When they arrived at the mooring site in the morning, the Cyclo-Crane was dashing itself against its own moorings. Apparently, it was pulled loose from a tether in a high gust."

Aero Lift, working with an \$850,000 U.S. Forest Service contract, is rebuilding the heavy lifter and will start tests

later this year. The lifter has a cockpit in its nose and can carry a gondola beneath the airship for more instrumentation or additional crew.

Other airship experiments in the works center on the vessel's potential as a radar platform. Goodyear has mounted a radar system on the airship *Enterprise*, demonstrating to the Coast Guard its maritime control capabilities in flights over the South Florida coast. The Navy, which last year commissioned Lockheed to develop a concept for an airship that can hover at 70,000 feet to perform the same tasks as a spy satellite, has also asked airship developers to come up with radar concepts.

On several certification flights, the Skyship 500 has been equipped with a radar boom mounted inside the main airbag which tested out successfully.

The Skyship envelope is laminated polyester sandwiched between layers of polyurethane and gas-retention film. The envelope fabric was designed for Airship by a French chemical company. Inside the envelope are two large bags that can be filled with air scooped in through lightweight pipes running to the outside of the skyship. These air bags—called ballonets—are made of Polyamide 66 woven fabric and coated with polyurethane spray. In flight, the ballonets have a maximum air capacity



A model of Piasecki's heavy lifter (above) shows the four helicopters adding to the airship's lift and speed. The airship undercarriage (right) has been completed and the first chopper (below right) was mounted late last year.



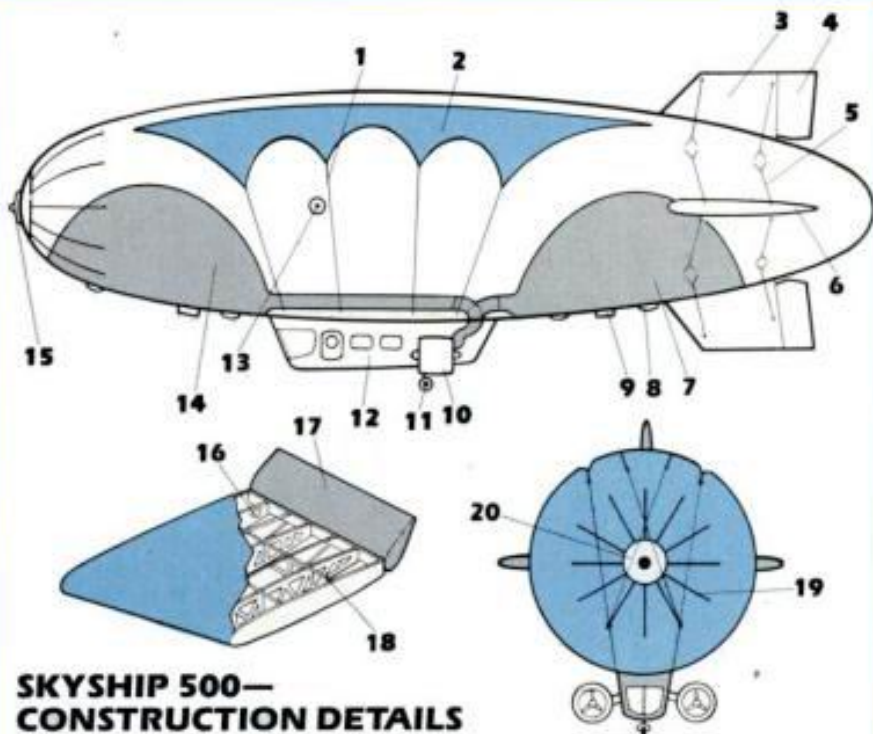
of about 40,000 cu. ft. each. They must be kept in balance—there's a ballonet fore and aft of the ship's gondola—to minimize surge, the sudden turning of the ship's nose sharply up or down. Also helping to keep the ship's flight stable are six 20-inch valves, two in each ballonet and two in the midst of the envelope.

Ride like a submarine

Flying an airship has often been compared to running a submarine. The ship has to be kept as close to perfectly stable as possible or it will go into a killing dive. Of course, pilots who have flown the Skyship 500 think of it in gentler, more romantic terms.

"Flying a nonrigid is similar to operating a light aircraft," says Nick Bennett, chief test pilot for Airship. "You just need to know Boyle's law (stating that gases expand with heat and

(Please turn to page 190)



SKYSHIP 500— CONSTRUCTION DETAILS

- | | | |
|------------------------------|-------------------------|-------------------------------------|
| 1. Kevlar gondola cables (8) | 8. Ballonet air valve | 15. Nose probe for tether |
| 2. Gondola support curtain | 9. Air blower | 16. Nomex ribs |
| 3. Tail fins (4) | 10. Engines (2) | 17. Nomex rudder |
| 4. Plastic rudders (2) | 11. Landing gear | 18. Nomex spar |
| 5. Wire bracing for tail fin | 12. Kevlar gondola | 19. Nose battens (externally laced) |
| 6. Plastic elevators (2) | 13. Emergency air valve | 20. Molded nose cone |
| 7. Aft ballonet | 14. Forward ballonet | |

MILITARY



Container ship seen here was among a dozen that ferried helicopters for the British during the Falklands war.

Good aircraft carriers are hard to find

They move quickly and carry big flying arsenals on their broad backs. But today's aircraft carriers are too easy to spot by spy satellites. Getting a carrier out of port in an emergency might, therefore, pose big problems. Of course, today's navies have Harrier jump jets that can take off from decks much smaller than carriers (see *Falklands Diary Of A Harrier Pilot*, page 59). That's exactly the kind of thinking that has inspired the design of two systems—one British and the other Ameri-

can—to convert container ships into carrier vessels.

The British—whose Harriers controlled the South Atlantic in last summer's war for the Falklands—are developing SCADS, or Shipborne Containerized Air Defense Systems. British Aerospace, Plessey and Fairey Engineering have collaborated on the project, which so far is mostly on paper. With a specialized radar system, an electronic decoy system and an antimissile system, the SCADS

deck can transform a container ship into a unique carrier as the civilian vessel steams out of port. The entire change would take 48 hours.

The American system, developed by the Navy under orders from Congress, is called Arapaho, for the American Indian tribe.

Both changeover systems depend on fast, 30-knot-plus container ships; standard-size containers that can be moved easily on trucks and trains; and production aircraft such as the

MEDICINE

Body pictures by the numbers

Basic arithmetic and computer and X-ray technologies are the seeds of a new diagnostic technique that gives the closest look yet inside the body's circulatory system. The University of Michigan Hospital and several other institutions say they are making early and accurate diagnoses of a wide range of ailments using "digital subtraction angiography" (DSA).

In a radiological version of paint by numbers, X-rays are transmitted through a patient's body forming both the usual internal image and a computer image. Each of the images' 250,000 pixels is assigned a number based on the density of the organ through which the X-ray penetrated. A first X-ray shows everything but the blood vessels of an organ. A second X-ray, taken after the patient is injected with a dye, shows only the shadows of veins and arteries. The computer subtracts dense tissue from less-dense tissue, forming an enhanced image.



To get a clear picture of kidney veins and arteries, (left) the Michigan system combines two X-ray images. Then, technician uses "digital subtraction," forming enhanced image.

Editor: Dennis Eskow
Contributor: Charles Reina

TECHNOLOGY UPDATE



American container ship converted to Arapaho helicopter carrier for military missions is seen here in artist's concept. Off the port bow is a British SCADS container ship with ramp for Harrier launching.

PM art: Donn Ellis

Harrier. Both SCADS and Arapaho are pre-packaged and stored with all radar, electronics and ammunition inside. The SCADS containers would support a bridge-type ski jump for Harrier takeoff.

The British couldn't get a SCADS into production for the Falklands combat, but they were able to convert a dozen container ships. These carriers transported Harriers and Sea King helicopters from England. Had they been able to use SCADS, they would have had extra takeoff area. The flexible ski jump is strong, supported by standard bridge cribs, special

jacks and towers or scissors jacks. A runway as small as 200 feet can be assembled to accommodate the jumping jets. For a vertical landing, a Harrier needs no more space than a helicopter.

The ski jump is based on the kind of takeoff platform already used on small British carriers. That jump, which is built into the ship's deck, makes it possible to keep a large number of aircraft topside during actual combat flight operations.

The implications for both SCADS and Arapaho are mind boggling. Today's supercarriers

cost \$2.5 billion to complete. A container ship, notes Arapaho project director James Mulquin, costs \$50 million to \$75 million. Conversion to either system would cost about another \$20 million.

"The Arapaho program could extend the U.S. Navy's at-sea aviation bases from the present 150 to 160 vessels (including patrol boats that carry single helicopters) by about 60 to 80 container ships," Mulquin says. That kind of figuring promises to make Arapaho an American mainstay, and SCADS a British standard, for some time to come.

RECREATION



TRAVEL CHARGE

If you work in Odense, Denmark, you can drive an electric bike to work. Leave it at one of the town's "Parkelmeters" for an hour or more and you can drive home with a recharged battery. The town's 24-volt charging stands are coin-operated and have an automatic cutoff.



ISLAND IN THE SKY

Picture-snapping tourists at Cypress Gardens, Fla., next month will ride Kodak's hydraulic platform 150 feet in the air. The tower will carry about 100 people per trip.

TECHNOLOGY UPDATE

It's all in that funny wing on the nose

Aviation

"What's that funny wing on the nose?" People have been asking this ever since famed aircraft designer Burt Rutan unveiled his odd-looking VariViggen in the early '70s, followed by the popular little homebuilt VariEze and Quickie—all spectacular, if unorthodox, sports planes, with wings on their noses (see *The Wizard of Homebuilts*, page 116, Feb. '79).

Now Rutan is thinking bigger. His latest adventure into the exotic is a 36-passenger, twin-engine airliner intended for fast, safe, intercity commuter service, a field currently dominated by STOL-type imports of foreign design.

Like Rutan's earlier creations, the new commuter-shuttle concept sports a tail-first horizontal stabilizer called a "canard." Its principle is intriguing. Set at a slightly sharper angle than the main wing, it stalls out first as speed decreases. This

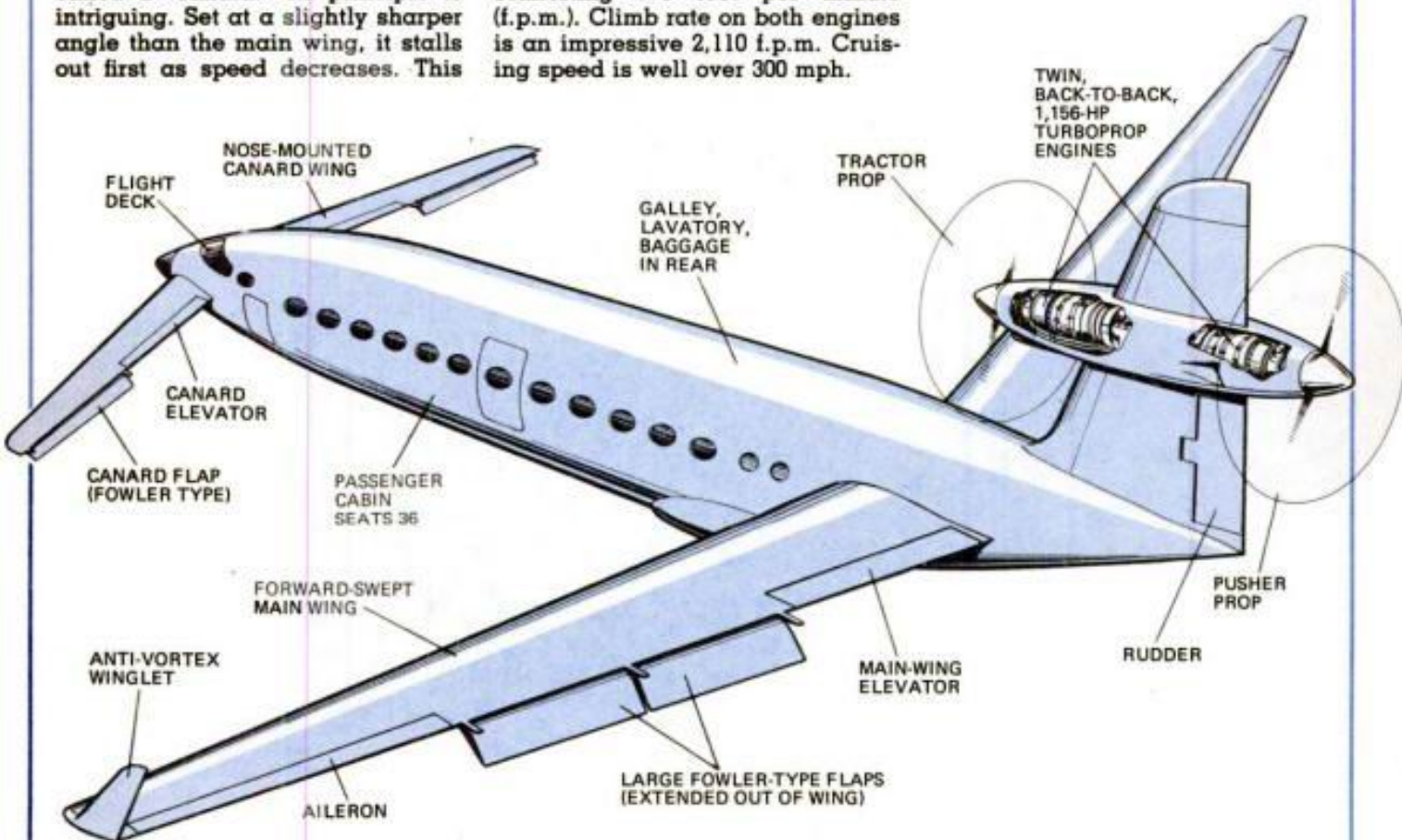
drops the nose, increasing speed automatically and regaining lift before the main wing can stall. Thus, the craft itself never fully stalls—and a plane that can't stall won't go into a spin.

But the canard is only part of Rutan's maverick philosophy. The engines aren't on the wings, where you'd expect them to be. The two, 1,156-hp Pratt & Whitney PT6-45 turboprop powerplants are in the vertical tailfin, one ahead of the other—one pushing, the other pulling. Because the engines are in line with each other, there's no sudden yaw to the side if one loses power—a reaction so violent it can cause a conventional twin to lose altitude and go out of control.

The Rutan commuter, modestly designated the Model 78-I, not only can maintain altitude on one engine; it actually can continue to climb at a comforting 770 feet per minute (f.p.m.). Climb rate on both engines is an impressive 2,110 f.p.m. Cruising speed is well over 300 mph.

While not strictly a STOL configuration, the 78-I is designed for small-field operation. Duplicate elevators and flaps in both the canard and main wing give it high lift and precise control, especially at low landing and takeoff speeds. With flaps down, it can land at a relatively tame 94 mph.

The 78-I is 65 feet long, has a main-wing span of 70 feet and burns an economical 505 pounds of fuel per hour. A scale model is currently undergoing wind-tunnel tests at NASA's Langley Research Center. If the results are as good as the preliminary calculations, Rutan's remarkably prolific Rutan Aircraft Factory in Mojave, Calif., may have the makings of a speedy, fuel-efficient, supersafe commuter shuttle that could pose a U.S. challenge to foreign competition—even with the funny wing on its nose.



Let it all hang out: With dual control surfaces, the craft has superb low-speed maneuverability, needs only 3,500-foot runways.

ENERGY

Drill deeper, cheaper

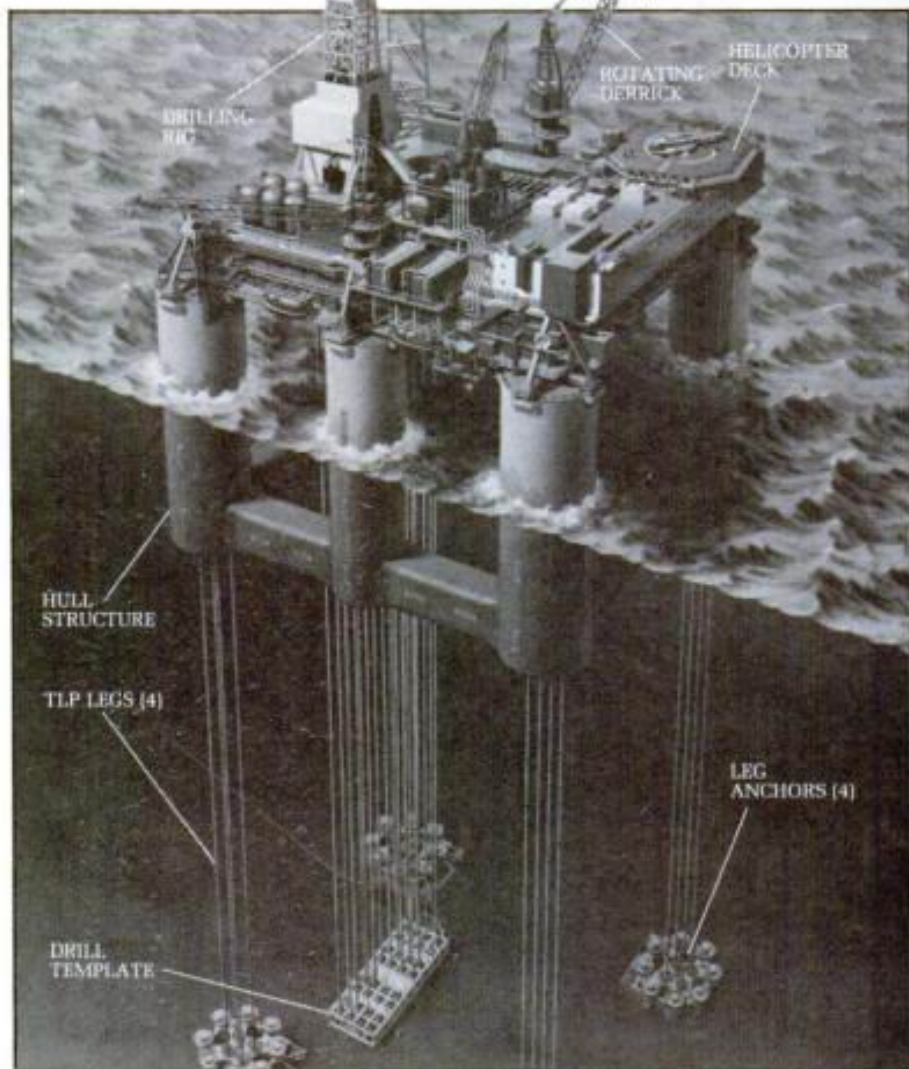
A new kind of oil rig platform will be floating in the Hutton field on the North Sea next summer. Conoco's Tension-Leg Platform, with its 243- by 268-foot upper deck, is built to handle the most difficult parts of oil exploration.

For one thing, it is designed to work in water even deeper than Hutton's average 485 feet. And, since a TLP floats, one platform can work in several areas without the high costs of foundation-building that permanent platforms require. The TLP's "legs" are steel tubes held down by weights. Beneath the center of the 61,000-ton platform are the well templates. In the drawing at right, well holes have been drilled through the heavy steel templates. The drill is lowered into the ocean in 25-foot lengths.

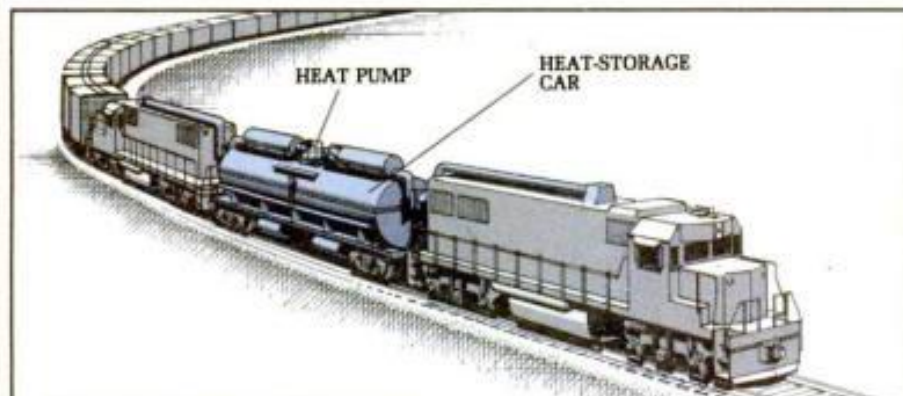
The all-steel hull is semisubmersible. It carries a three-level deck, the top of which includes a helicopter landing pad, drilling rigs, rotating derricks and other equipment. The second and third levels house the crew, equipment and generating station. All this sits atop six steel columns that hold the mooring legs in tension with upward buoyant forces against the columns and against the pontoons that stretch between them.

The 100-ton crane would move on a rail. One advantage to this floating island would be its ability to handle a fire. Pumps just below decks could provide an immediate and steady stream of water.

The hull structure contains water ballast to help keep the platform righted in high seas. Gulf Oil, Amoco and Brit Oil went into this venture with Conoco, which expects TLP rigs to be operated by most oil companies by the end of the this decade.



Conoco's floating Tension-Leg Platform oil rig is expected to be operating next summer.



GREAT TRAIN RECOVERY

A diesel-electric locomotive vents a lot of heat into the atmosphere, which is why Thomas Williams has patented his Locomotive Energy Recovery System (U.S. Patent 4,342,921, issued last summer). A heat pump carries exhaust heat

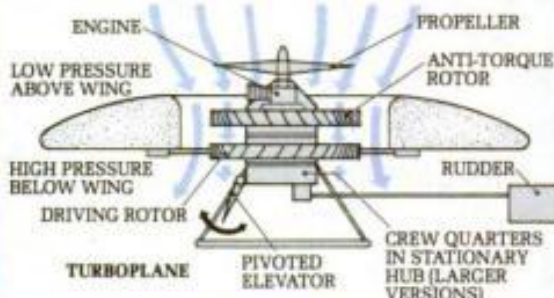
from the locomotive to a tanker car filled with a storage fluid. The heat can be used to warm railroad cars or conduct industrial processes, such as alcohol production. In another rail car, Williams says the car could uncouple for factory use.



ENERGY PROGRAM

Small supermarkets and restaurants this summer will be able to monitor and control as many as 20 temperature and humidity sensors from different areas with one microprocessor-based control system. Honeywell's W7000 interfaces with a personal computer.

AVIATION



New flying saucers: Freaky and far out, but maybe for real

The next time you look up in the sky and think you see a flying saucer, it just might be the real thing—though not filled with little green men from Mars. Two serious flying saucer concepts under development here on our own planet may point the way to exciting new shapes in commercial and recreational aviation. Both are VTOL-type aircraft, permitting vertical takeoffs and landings right in your own back yard. Unlike helicopters, however, they use small, ducted-fan props for lift and propulsion, saving the cost and complexity of huge, ungainly rotor blades.

The Turboplane (above, left) is the creation of Austrian inventor Heinz Jordan. In its present form, it's a whirling, doughnut-shaped wing, about 3 feet in diameter, that looks like an overgrown, motorized Frisbee. Though only a radio-controlled model, it's a prototype for much larger, man-carrying versions. A small, horizontal propeller draws air down through an opening in the center, creating a high-speed, low-pressure flow over the wing and a low-speed, high-

pressure flow under it. At the same time, a controllable-pitch rotor attached to the rim spins the circular wing like a toy pinwheel. A second, fixed rotor, with reverse-pitch vanes, exerts a counterrotating force on the central hub to keep it from turning, thus eliminating the need for an anti-torque tail rotor such as the ones helicopters require.

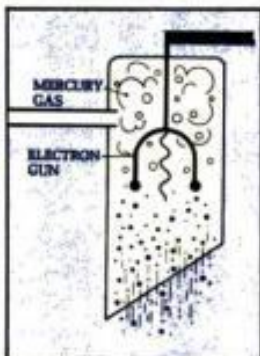
The upward force of high-pressure air below the wing, the downward force of the ducted airstream, and the gyroscopic effect of the spinning ring all combine to produce tremendous lift, thrust and directional stability.

Like a helicopter, the saucer is tipped slightly downward for forward flight, but requires no complicated cyclic or collective pitch controls. A tail rudder steers the craft, while a pivoted forward vane acts as an elevator for pitch control. For fast maneuvers, the spinning ring can be slowed down through the adjustable-pitch rotor to lessen its gyroscopic resistance to turns. If the engine fails, the prop continues to

AEROSPACE

Thrustworthy ions

Later this year, a Titan-rocket-launched satellite, on an earth resources mission, will use an engine never tried outside a lab. The Hughes Ion Thruster Engine will be used to make slight changes in the satellite's attitude once in orbit. The thruster uses a solar battery to build up a charge in an electron gun that fires a stream of electrons through mercury gas, knocking free other electrons. As electrons fly out the conical thruster, the satellite moves in the opposite direction. Ion thrusters may someday make space travel as cheap as solar energy.



Ion thruster has been used only in the lab.

New jet engines are fuel sippers

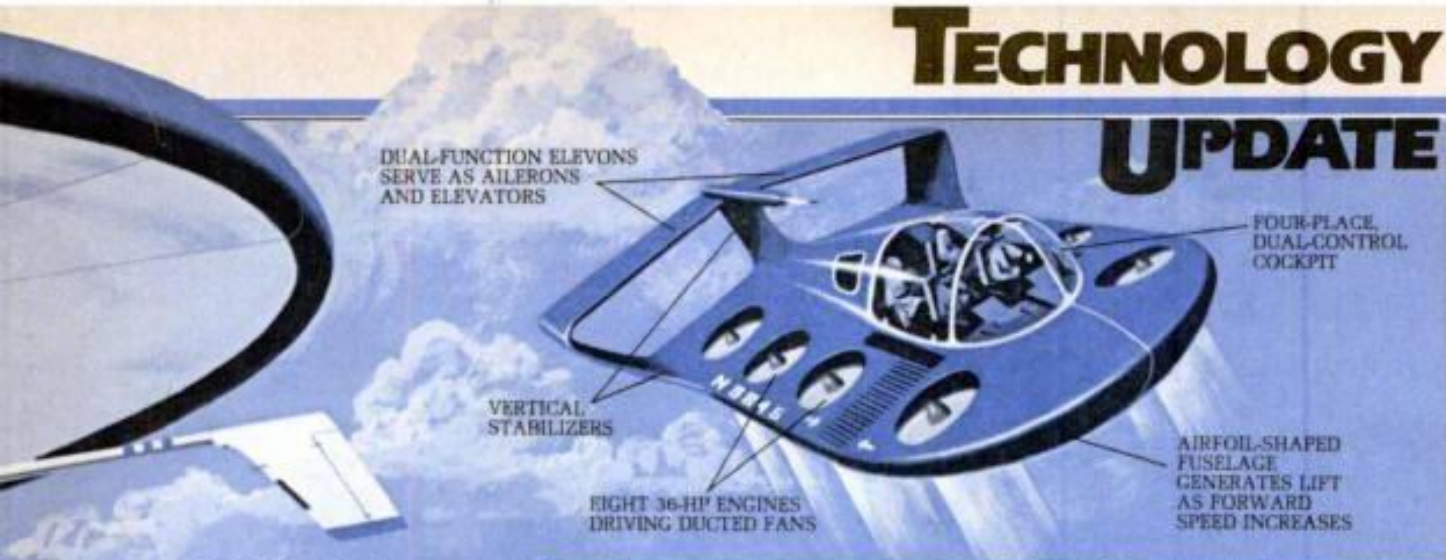
Pratt & Whitney's two newest jet engines, the PW4000 and the PW2037, promise to cut the cost of running an airline. Both have fewer moving parts than their predecessors, cutting maintenance costs. And both deliver up to 7 percent better mileage than P&W engines of similar size. The 2037 was certified for the Boeing 757 last December. The 4000 will be ready for certification in 1986.



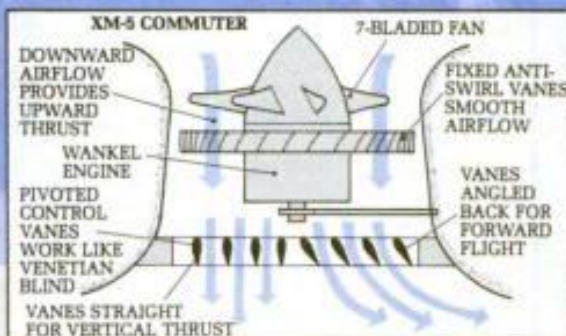
Pratt & Whitney's PW2037 sips fuel, has fewer moving parts.

Editor: Dennis Eskow
Contributors: Sheldon Gallager, Alcester R. Oberg, Allan Lundell, Geneen Marie Haugen, Frank A. Tinker, Franklyn Peterson

TECHNOLOGY UPDATE



Prototype of XM-5 (far right) is a one-man, tailless saucer, but production version (artist's concept at upper right) will be sporty four-seater with a triple-finned stabilizer using two-way elevator/aileron for control. Cutaway (near right) shows how air can be ducted downward for vertical lift or rearward for forward thrust. On facing page (far left) is 3-foot-diameter R/C test model of revolving-wing Turboplane. Cutaway shows how one rotor spins wing, while a second, counterrotating rotor keeps hub stationary. Artist's concept (upper left) depicts what a full-size passenger liner or cargo freighter might look like.



PM art: Dean Ellis

autorotate, providing sufficient lift to make a safe, emergency landing like an autogyro.

The unusual Turboplane configuration is said to have a potential payload capacity of more than twice that of current heavy-lift helicopters of comparable power. In full-scale production versions, crew quarters, passenger accommodations and cargo space will be located in the central, stationary hub. In the meantime, the prototype Turboplane will be sold as an R/C model for hobbyists. The price is about \$200, less engine and radio control, from Ferdinand Kristoff, Austrian Investment Counsel, 1126 North Swan Rd., Tucson, Ariz. 85712.

Another saucer-like design is the XM-5 Commuter (above, right), a futuristic, four-seat aerial runabout that could be a moviemaker's prop for a film like *Star Wars*. Conceived by Dr. Paul Moller, a California professor of aeronautical engineering, it's capable of making vertical takeoffs and landings, but once aloft, flies much like a conventional sports plane. Unlike the rotary-wing Turboplane, it does not spin like a top, but has a fixed, airfoil-shaped fuselage fitted with a bubble canopy and a rakish-looking, triple-finned tail. Eight 36-hp Wankel-type

engines, driving small, ducted-fan props around the rim, provide a total of 288 hp for speeds up to 215 mph.

Advantages claimed for the multiprop array are highly sensitive control response, self-canceling torque, simplified engine maintenance and the security of redundant power. The craft will continue to fly with any four of its eight engines disabled and can even land safely on two.

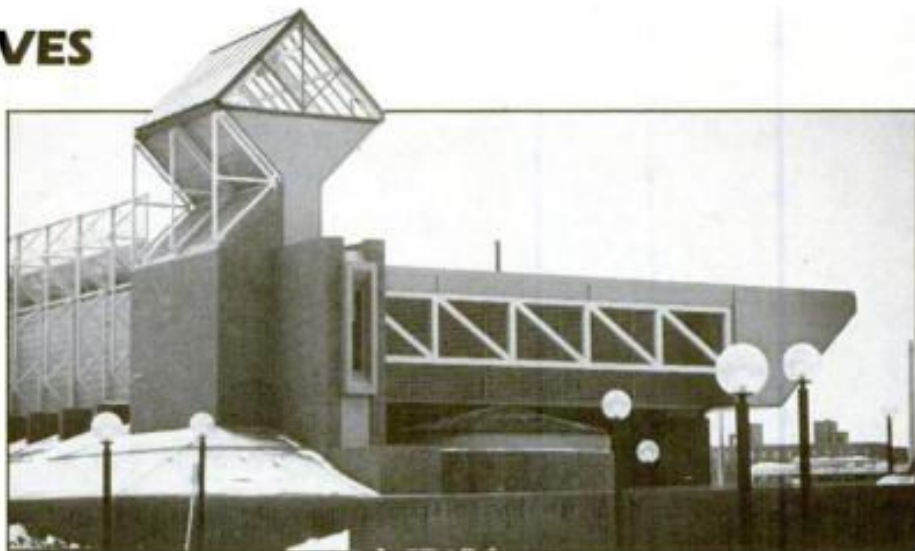
Rows of computer-controlled louvers in each duct, which work like Venetian blinds, can be angled to direct the airstream downward for vertical thrust or rearward for forward thrust. Used differentially on opposite sides, they also steer the craft at low hover speeds when there is little or no airflow over the control surfaces. At high speeds, dual-function elevons in the tail operate collectively as elevators for pitch control and differentially as ailerons for roll control.

Approximately 15 feet in diameter and made of molded fiberglass parts, the exotic XM-5 will be available in kit form later this year. The anticipated price is around \$25,000 from Moller Corp., 1222 Research Park Dr., Davis, Calif. 95616.

ALTERNATIVES

Underground courses

Engineering has gone underground at the University of Minnesota. The school's engineering lab just completed its first semester in a six-story underground building that houses classrooms and studios for drawing and modelmaking. The building's roof and cooling system stick up out of the ground. The builders say it cost 10 percent less to complete the structure than it would have for the same space above ground. It'll also cost far less to heat and cool since the surrounding glacial rock and limestone maintain local temperature at a constant 55°F. Solar panels provide the little heat needed to give the building some hot water. Light is all electric.



Only roof and cooling system are above ground on Minnesota's six-story engineering lab.

UPDATE



MARINE

Cruise ship for the future

The great luxury liners of the past may not be dead. By the turn of the century, exotic twin-hulled vessels like the one above may be treating ocean travelers to a splendor not dreamed of even on the lavish *Queen Elizabeth* and *QE II*. Called the *SWATH 2000*, the floating palace is an advanced concept proposed by Wartsila, a leading Finnish shipbuilder that is famous for its glitzy cruise ships and mammoth seagoing ferries.

SWATH stands for Small Waterplane Area Twin Hull. The 2000 refers both to the year 2000 and to the fact that the ship is designed to carry 2,000 passen-

gers. Unlike a conventional catamaran using displacement-type hulls, the *SWATH 2000* employs slim, surface-piercing struts connected to long, thin underwater pontoons. These provide the stability of a catamaran but with much less drag, while the broad platform base permits a superstructure of tremendous area.

In the *SWATH 2000*, the cabin decks are arranged around a huge, open-air atrium that houses a swimming pool, shops, game rooms, snack bars, cocktail lounges, health spas and other recreational attractions. This layout enables all staterooms to have an outside view,

either toward the sea or overlooking the atrium. A sumptuous dining salon, sweeping upward through three deck levels, is capable of seating all 2,000 passengers at one time. In bad weather, a sliding roof will be used to enclose the atrium.

The *SWATH 2000* is expected to have a cruising speed approaching 30 knots. Her widely spaced twin engines, with adjustable-pitch propellers, will permit turn-on-a-dime maneuvering by throwing one prop into reverse—much the way a battle tank pivots on opposite-turning tracks.

Meanwhile, our own U.S. Navy is



'STAR WARS' WARSHIP

What a 21st-century warship might look like is shown in this dramatic painting by a U.S. Navy artist. While the Navy isn't saying just when we will see the new ship, it clearly incorporates known technology: hydrofoils for fast, agile maneuvering, streamlined "stealth" contouring to fool enemy radar, even vertical-launch fighters poised for quick takeoff.



A SHIP THAT TUGS 'BUGS'

The USNS *Stalwart* is the first of 12 T-Agos-class surveillance ships that will drag electronic equipment in U.S. coastal waters in search of submarines. A large winch on the rear deck drops sonobuoys that pick up sounds. The *Stalwart* is stationed in the Atlantic.

ALTERNATIVES

Icing on the cake

Enerplex is a twin-building office complex in Princeton, N.J., that opens this summer with an array of energy-saving devices. But the icing on the cake is a half-acre domed "ice pond."

Prudential Insurance, financier of the project, will run tests on the pond this summer. An 8,000-ton, 20-foot-high mound of ice is built up layer by layer all winter. The plastic wall of the dome is layered with a chemically treated, subfreezing fog and the inside walls are coated with ice. Winter temperatures form the ice mound beneath the dome. In warm weather, the ice pond is sealed off from outside air. Fans will blow its cool air through the Enerplex buildings for air conditioning.



SWATH carrier would be highly stable.



Twin-hull frigate could look like this.



Sub hunter could operate in heavy seas.

also eyeing the SWATH concept for use in a new breed of high-speed, super-stable warships. Already on the drawing board at the David W. Taylor Naval Ship Research Center are plans for several twin-hull vessels, such as the mini aircraft carrier, frigate and antisubmarine patrol boat shown above. In addition to greater speed and maneuverability, the chief advantage of the SWATH design lies in its uncanny steadiness in heavy seas. Critical battle functions, like the launching of aircraft, could be carried out in seas too rough for conventional monohull vessels to operate.



Washing up the water supply

This summer, Denver will open the nation's first potable water reuse plant. The \$29 million complex (shown in the drawing above, right) will produce 1 million gallons per day of drinking water from treated sewage. Water treatment plants generally use four purification steps. But the municipal water in scores of cities has dwindled in quality over the past 25 years

despite those steps. The Denver plant employs 11 steps. There is an ion exchange to remove ammonia, a system to produce fertilizer, a three-step carbon adsorption process to remove organic matter, a reverse osmosis to remove viruses, a chemical addition to disinfect, and four steps of disinfection and aeration. An ionization tank is shown above, left.

AUTOMOTIVE

Hummer of a tire

The Army's new jeep replacements, nicknamed the Hummer, have already spun out something new for civilians. Motor Wheel Corp.'s run-flat tire copies the military version by placing a metal wheel within the tire. If the tire goes flat, a vehicle can still move at 30 mph for more than 20 miles. Bolts clamp the inner tire to the wheel so it stays in place. Fire trucks and ambulances will be using the wheels by the end of this year.



Wheel-within-a-tire (left), developed for Army's new jeep (above), is now made for civilian trucks.

AVIATION



Strange new shape for tomorrow's SST

The twin-bodied jetliner above may not be as crazy as it looks. It might just be the answer to America's long-sought supersonic transport, a program killed by Congress in the early '70s. Now, despite the economic problems that have plagued the Anglo-French Concorde, there's renewed interest in a U.S. SST.

According to Lockheed, the key to an economically viable SST lies in a cheap substitute for costly jet fuel. One possi-

bility is liquid hydrogen (LH_2), which can be made from coal and other processes. The chief problem with LH_2 , however, is its very low density, requiring huge fuel tanks to carry a sufficient supply for transoceanic flight. As much as half the space in a conventional airliner would have to be given over to fuel storage (inset, above), leaving little room for passengers. The fuselage would then have to be made much bigger, and the result would be higher

drag and vastly increased power requirements.

One answer, says Lockheed, is the twin-fuselage configuration. The reason: Two long, slim fuselages are aerodynamically more efficient than a single fat one. They would permit more speed on less power and at the same time provide plenty of space for both fuel and passengers.

Lockheed has also found a way to reduce the objectionable noise level of

WEATHER

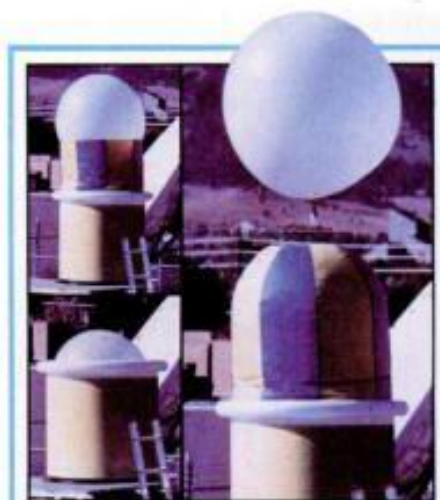


Struck by lightning

The old saying that lightning never strikes twice in the same place doesn't apply to NASA's F-106B test craft. The plane has attracted more than 250 lightning hits since 1981. The jet will help determine the best thickness for airline body material and will experiment with devices to protect avionics from lightning surges. In addition to sensors, the jet carries cameras to

record the direction and shape of lightning strikes (inset). So far, tests have shown that lightning hits aircraft most in the nose and tail. The heavily instrumented F-106B flies out of the Langley Research Center.

Editor: Dennis Eskow
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Douglas A. Hilton



WEATHER BALLOONS

The National Center for Atmospheric Research has developed a weather balloon whose 400-mHz. transmitter sends data to three ground stations. As the balloon rises to the stratosphere, the stations receive different Doppler-shifted readings on temperature and humidity. A central computer then creates a three-dimensional storm chart for highly accurate weather predictions.



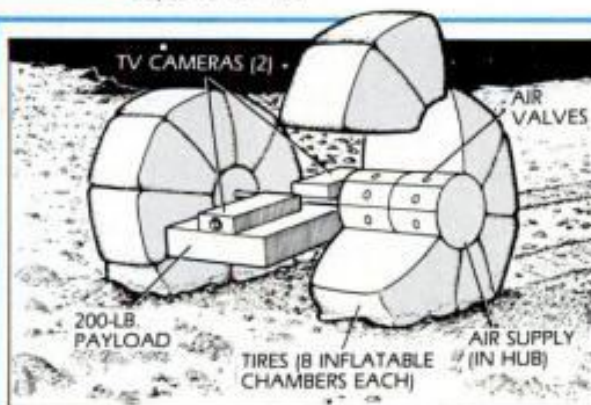
FUTURISTIC FLIGHT DECK

It's not the bridge on the starship *Enterprise*—it's a NASA simulator for testing out new concepts in cockpit design for tomorrow's airliners. All flight information is displayed on video screens and commands are issued by voice or keyboard. The object: to simplify control, reduce pilot fatigue and save fuel through more efficient navigation.



SPACE

an SST. The idea is to stack the engines one above the other instead of stringing them out in a row. Through a process known as acoustic shielding, the exhaust from the lower engines masks the roar of the upper ones, making four engines sound almost as quiet as two. Liquid hydrogen is not yet cheap, but it could be if efficiently mass-produced. When that day comes, twin-bodied SSTs, traveling at Mach 3, may whisk you to Paris or Tokyo in a few hours at no more than the price of a regular air fare for an all-day flight.



MARS BALL WILL ROLL

A University of Arizona team is developing a vehicle for possible use on missions to Mars. The tires on the Mars Ball have eight chambers. Each chamber deflates as it touches the ground, and the chamber behind it inflates, propelling the vehicle. NASA is studying a 1990s mission to Mars.

MEDICINE

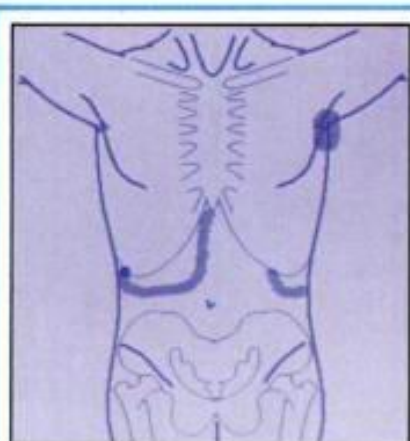


A neutron bullet for cancer

Some forms of cancer untreatable by chemical or X-ray therapy seem to respond to a bombardment of neutrons. The Fermi National Laboratory's Neutron Therapy Facility has been tapping neutrons from Fermi's physics experiments.

In the still-experimental treatments, protons are diverted from the Fermi accelerator to a beryllium target, scat-

tering neutrons in all directions. Tapered holes in the patient's room direct neutrons toward the patient, who is positioned to allow the neutrons to strike the tumor only (above, left). Laser beams are used to align the patient (above, right). It's still too early to tell whether the neutron treatment can be used at other institutions across the nation.



HEALTH PROGRAM

Stanford University doctors are testing a computer program that will eventually help doctors determine when to order tests and treatments. Dubbed Onocin, the program creates a graphic of the patient's lymphatic system based on information from the doctor, then the graphic points out warning spots (above) that require treatment. It could be in use by the end of the decade.



BRINGING STAR WARS DOWN TO EARTH

BY EDWARD TELLER; Illustration by Attila Hejja

Physicist Edward Teller, senior research fellow of the Hoover Institute in California, was one of the chief scientists involved in the development of the hydrogen bomb. A former member of the President's Foreign Intelligence Advisory Board, Teller has been cited by President Reagan as his beam weapons adviser. Prof. Teller answers important questions about defense.

Is an effective defense possible in an age of atomic weapons?

The idea that the weapons of offense are too powerful to allow for an effective defense began with Hitler's early blitzkrieg victories in World War II. The Nazi attack, using a combination of fast-moving tanks, dive bombers and motorized artillery equipment, defeated Poland in days, and within six weeks

French and British without a toehold on the continent. Later in the war, the inaccuracy in bomb targeting led to vast urban destruction, and the atomic bomb—the "ultimate" weapon—seemed to be the final confirmation of the idea that no defense is possible. The destructive power of the atomic bomb, a thousandfold greater than conventional bombs, was soon surpassed by another thousandfold with the advent of



A "Star Wars" defense places the emphasis on space-based beam weapons, but also important are land-based beam weapons to defend inland and coastal areas, and ship-based and airborne lasers that will hit missiles before they reach their targets.



Artist's concept of an ASAT airborne missile to knock out satellites.

the hydrogen bomb. Coupled with fast-moving rockets, these developments in the 1950s provided the capstone for the idea that defense against modern weapons is impossible.

But defense is possible. In our era of ever-increasing technical change, a simple point remains valid: The extent to which a weapon is destructive does not determine the extent to which it is vulnerable to countermeasures. In other words, just because it's a superweapon doesn't mean that it can't be stopped from reaching its target.

There is a lesson in the relatively recent past that should not be forgotten. Prior to World War II, defense against aerial bombardment appeared hopeless. In spite of this, countermeasures were attempted by more than one group, most particularly by a relatively small group of British scientists and engineers who developed (and kept improving) the art of radar—that is the detection of airplanes at considerable distances, by day or night, in fair or foul weather. The success of their resistance should continue to inspire those who are determined to devise defenses even against nuclear attack.

The attackers did not win the Second World War. Defense, in the original meaning of the word, was not obsolete then, nor has it become so now. To ignore defense, to place all emphasis on retaliation, was a political decision made effective almost a quarter of a century ago.

On March 23, 1983, President Reagan questioned the completely lopsided policy of deterrence that is our current national policy. In his speech, the President made no specific proposals and offered no suggestions about the nature of protective systems. He simply suggested in a justified manner that we place more emphasis on defense.

Unfortunately, the increasing importance of technology to military affairs has caused a proliferation of secrecy. The contemporary discussion of defense proposals is carried out in an environment where the best publicized plans are those that are least feasible, and the excellent plans are unknown to the public.

Is the term Star Wars, a good description of this kind of defensive effort?

To many, Star Wars seems an appropriate description of modern defenses because thorough technological innovation is connected in the popular mind with science fiction. Although President Reagan's proposal was dubbed Star Wars so its opponents could ridicule it, remarkably enough, a considerable portion of the population took that designation in a most positive manner.

What technologies are available to build modern weapons of defense?

It has been proposed to populate space with defensive battle stations.

While this proposal fully justifies the designation Star Wars, its disadvantages are numerous and obvious. One most important consideration is that a proper defense must be less expensive than the countermeasures that would render it ineffective. Establishing the proposed battle station would be expensive and difficult, but it would be comparatively easy and inexpensive to shoot down. Already the United States has tested Anti-Satellite (ASAT) missiles designed to knock out offensive satellites.

But, imagine if you will an alternative method. There are half a dozen ingenious proposals that appear to satisfy the requirements for defense. Unfortunately, they are classified. We are trying to keep ideas secret even though we have excellent evidence that these same ideas are available to the leaders in the Kremlin.

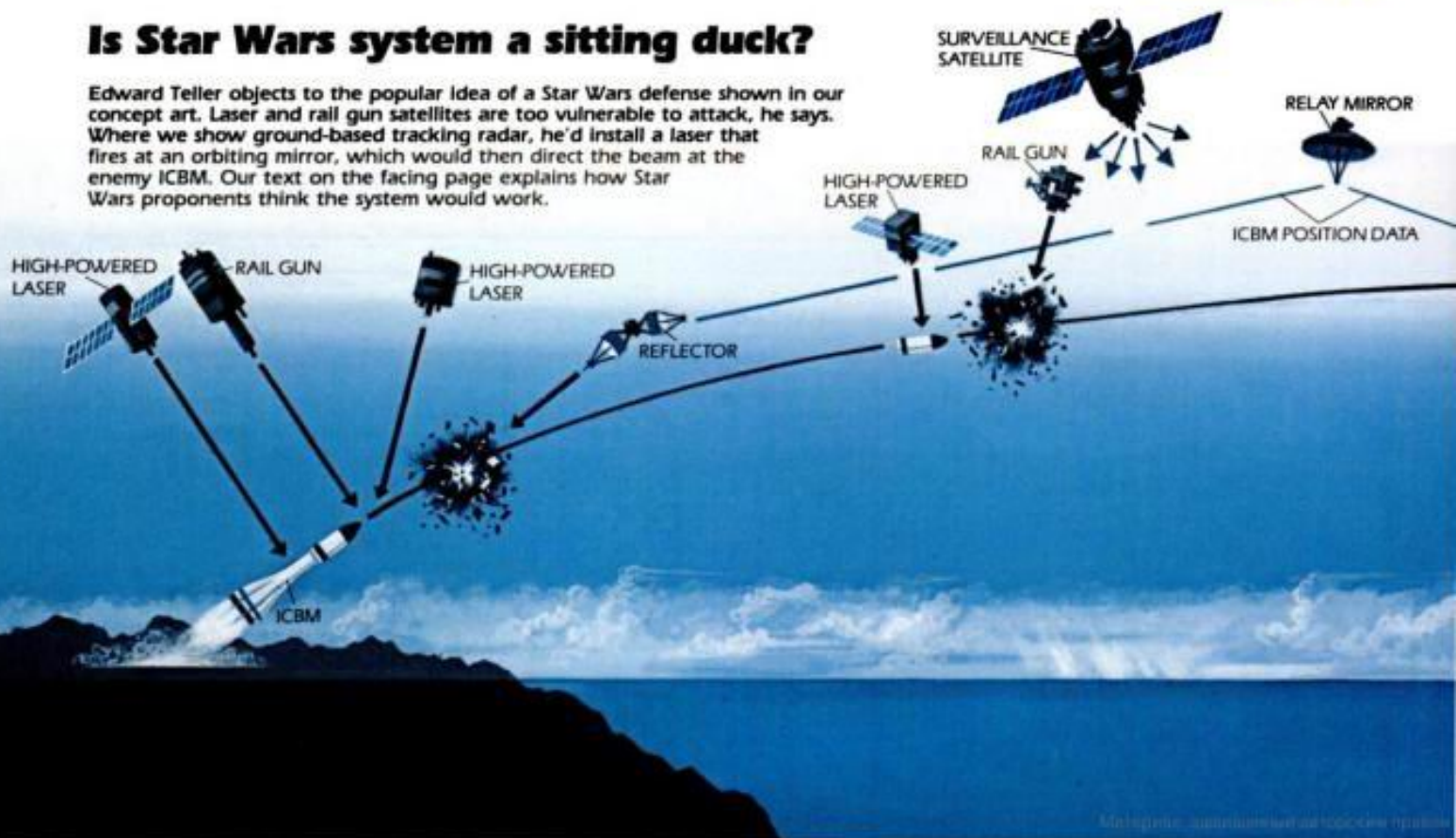
The Soviet people have no need to know since they have no possibility of influencing public policy. The American people have a need to know. They cannot possibly arrive at reasonable decisions if they are kept ignorant of the ideas that underlie defense. This does not mean that secrecy is completely useless and should be forthwith abolished. Details, blueprints, know-how can and should be kept secret at least for a while. Such limited secrecy has been practiced by industries for many years without interfering with informed decision-making.

Even though details cannot be given, one general idea is sound. Lasers, directional weapons that project energy in a

(Please turn to page 122)

Is Star Wars system a sitting duck?

Edward Teller objects to the popular idea of a Star Wars defense shown in our concept art. Laser and rail gun satellites are too vulnerable to attack, he says. Where we show ground-based tracking radar, he'd install a laser that fires at an orbiting mirror, which would then direct the beam at the enemy ICBM. Our text on the facing page explains how Star Wars proponents think the system would work.



Lasers and rail guns arrive

The future has arrived. Beam weapons are currently undergoing tests on Air Force aircraft and Army tanks. Last year, the message rang loud and clear after an Air Force C-135 with a strange-looking bubble-top shot down a Navy drone off the California coast. The weapon: a laser. Meanwhile, the Army is using an experimental track vehicle on a secret range to shatter small antitank missiles with a blast of laser light. And this summer, the Defense Department will conduct several tests on yet a new weapon in the unusual arsenal. Using a laser tracking device, the new Anti-Satellite missile (ASAT) will be launched from a souped-up F-15E flying out of Edwards Air Force Base in California.

Earlier this year one of the 18-ft.-long missiles was launched from an F-15E,

which fired the device down the Pacific testing range. Radio Moscow quickly accused the United States of planning to hit Soviet space satellites with ASATs. The weapons have no explosives in their warheads. Instead, the missile is designed to break up an enemy satellite by collision.

While laser anti aircraft guns and ASATs are undergoing further tests, labs across the nation are working on a slew of beam weapons designed to operate from land bases, ships, aircraft and other vehicles.

"It takes six millionths of a second for laser light to travel one mile," a declassified Defense Department report says. "And in that time a supersonic airplane traveling at twice the speed of sound will travel only a little more than one-eighth inch."

The next generation is rail guns—weapons that fire electrons or neutron beams at a target with far greater power than any laser could muster. Officials of the Defense Advanced Research Projects Agency (DARPA) say rail guns could be ready for deployment some time after 1995.

The basic laser being used today is the Gas Dynamic Laser, or GDL. Burning carbon dioxide with nitrous oxide, the GDL produces high energy carbon dioxide that sheds powerful bundles of



Air Force C-135 (top) with a domed top carries a prototype laser gun. Inside dome (above) laser mirror swivels and fires.

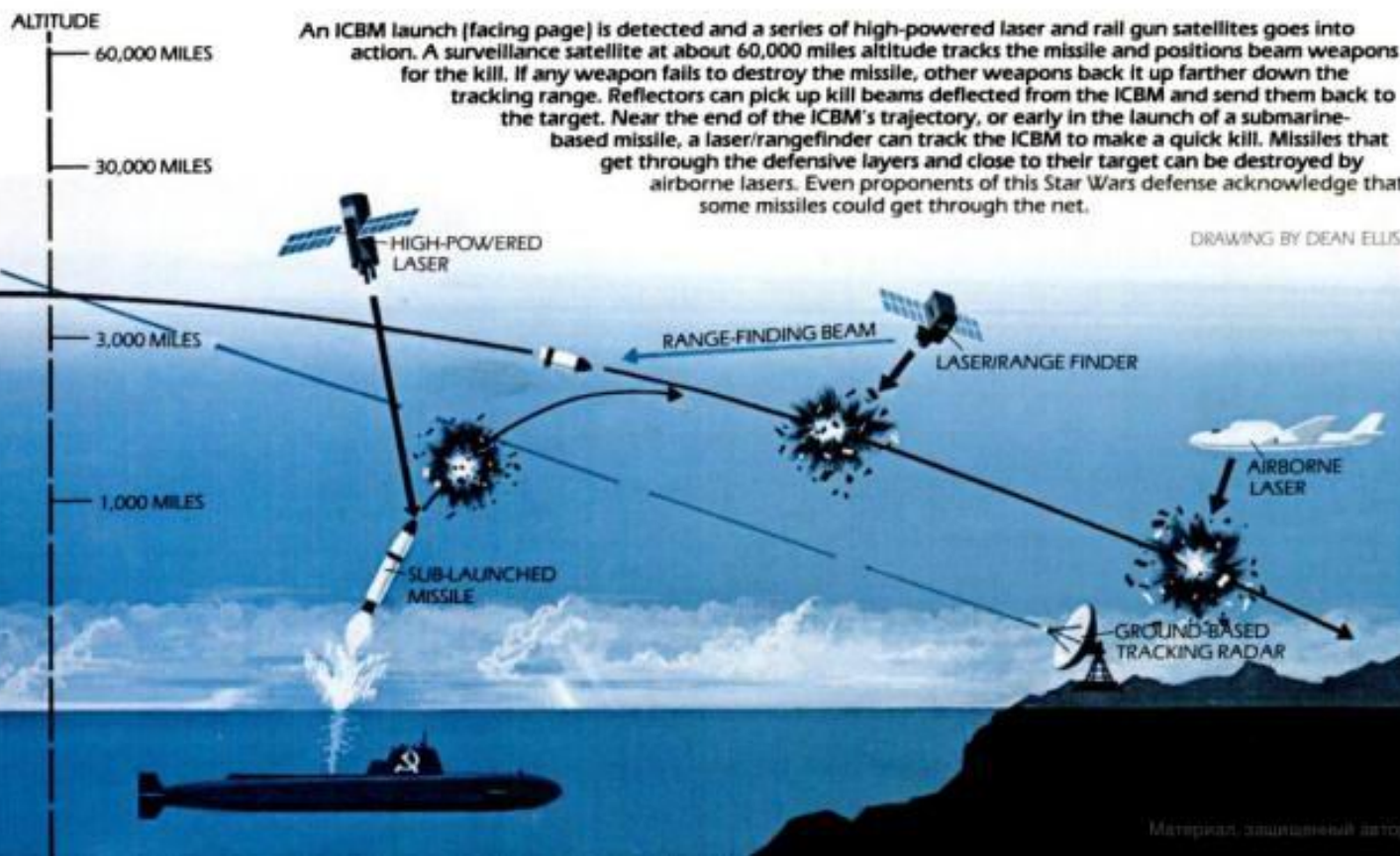
light on a target. Some experiments underway this summer involve an even more powerful Electric Discharge Laser (EDL). The more powerful weapon can burn a hole through an aircraft's skin in fractions of a second. The weaker GDL penetrates some aircraft materials, but there are ways to "harden" a plane or missile against it.

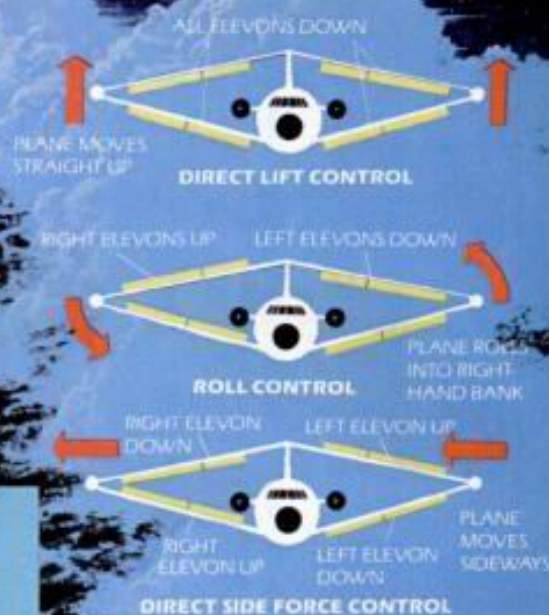
Still, DARPA officials favor the GDL because, in addition to being able to kill some aircraft, its waves of energy can disrupt radio signals and take a guided missile off course.

In testimony before the Senate Armed Services Committee, DARPA officials have said the Soviet Union may already have deployed high-energy GDLs around land bases near Moscow and perhaps aboard orbiting satellites. But they emphasize that the United States has taken an early lead in the technology, and if there is a beam weapons race, the Soviet Union is playing catchup.—D.E.



Artist Paul Alexander's idea of Star Wars (*Quantum War: Beam Weapons in Orbit* page 98, Nov. '81).





Funny wings for future airliners

Adaring new idea in wing design may enable airliners of the future to fly at supersonic speeds without the weight, drag and huge power requirements that make the present-day supersonic Concorde expensive to operate. Known as a Joined Wing, it actually consists of four wings, one pair sweeping backward from the nose and the other pair projecting forward from the tail, with their wingtips joined together to form a diamond. The result is a rigid, self-bracing structure that makes possible thinner, lighter wings without sacrificing strength, reducing aircraft weight by as much as 24 percent. The superthin airfoils also reduce drag.

The Joined-Wing concept, currently under study by the Office of Naval Research, offers other advantages as well. Unlike a horizontal stabilizer, the rear wings become lifting surfaces, not only helping to support the aircraft, but at the same time eliminating the power-robbing download that's imposed on a

conventional tail to keep a plane in trim. Multifunction elevons in all four wings make possible such trick maneuvers as moving sideways without turning, known as direct side force, and rising straight up like an elevator while remaining level, called direct lift. Such versatile controllability could simplify maneuvering in congested airspace and permit shorter, safer takeoffs and landings. A split rudder, its two halves fanning out like an open book, would serve as a giant air brake for killing speed during landings and aborted takeoffs.

What's the Navy doing working on a civilian airliner? Actually, it isn't. It all started with research aimed at producing a small, fast, unmanned cruise missile that, with folding wings, could be fired from a submarine's torpedo tubes. If this military application proves successful, the next step could be a scaled-up, NASA-sponsored passenger version for high-speed commercial air travel.

ROBOTICS

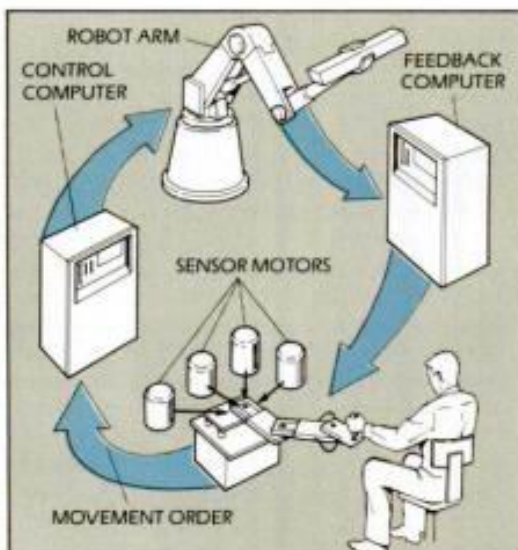
Robot feelings

The next generation of robots will let the operator feel what it's like to lift an object. That's important if your robot is handling a weapons detonator or a flask of germs. Gary Matthew and a University of Florida team are working on a "load sensor" system. The operator controls a robot arm with a remote sensor whose four motors adjust the feel of the joystick. This conveys to the operator the weight and balance of the object. The system uses two computers—one to control the robot and one for feedback.



PHOTO: HERBERT M. PRESS, UNIV. OF FLA.

Operator moves load sensor robot.



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Mark M. Meirero, Martin Louis Gardin



PHOTOS BY FRANK LUSK

Helicopter designer Frank Piasecki (above, right) introduced the helicopter-powered aluminum truss (top) that will power a 1 million cubic foot balloon (above, left).

Heavy lifter propped up

When finished next year, it will lift 100,000 pounds of lumber and carry it in the air for 50 miles. It's called the Heli-Stat, designed by Frank Piasecki, one of the earliest helicopter designers. The Heli-Stat's aluminum truss,

which will carry a 1 million cubic foot helium-filled balloon, was rolled out this past winter. On each corner is a modified H-34 helicopter that provides extra lift and steering capabilities previously unknown to airships.



SKYSHIP 600 FLIES

Britain's resurging airship industry (see *Airships Rise Again*, page 92, Apr. '83) is getting a new surge this summer with test flights of the Skyship 600. The craft, which has a 1 million cubic foot helium-filled Kevlar body, can carry 6 tons of passengers or freight. It is expected to see passenger duty in Greece in the fall. The airship's smaller forerunner, Skyship 500, is carrying passengers.

ELECTRONICS



FLYING DEW LINE

Maneuvering at 30,000 feet, an AWACS plane equipped with a new rig of sophisticated computers can code and decode radio information on enemy aircraft and missiles. The Joint Tactical Information Distribution System is the Defense Dept.'s new "flying dew line." The AWACS craft also are equipped with special jamming and unjamming software to thwart the enemy.



A PICTURE IS WORTH . . .

British researchers have created a video game to teach children how to speak properly. Pronounce the word correctly and an image forms. The images move at the proper commands.

ROBOT HAND EVOLVES

Some evolutionists say the thing that separates a human hand from an ape hand is the human ability to grasp tools. Now robots are evolving. MIT's Kenneth Salisbury has developed a three-finger robotic hand. The standard has been two fingers. The jointed hand will let robots do detailed work.



PHOTO: KENNETH SALISBURY, MIT

GUIDING ROBOT

Sir Plus is a new, \$1,400, 200-pound, 4-foot robot who works as a tour guide at the Palm Beach, Fla., Science Museum. Its ultrasonic eyes keep it from bumping into people as it follows an aluminum strip through the museum. It uses tiny sensors to feel its way along the tape. A pair of tape recorders carry the robot's "talk" as it leads people along, stopping at foil markers that switch off its motive power and turn on its vocal function circuitry.



PHOTO BY EDWIN J.C. SOBEY



NEW SUNDIAL

Pulsar Time Inc. has introduced a new solar-powered watch whose amorphous silicon crystal cells can recharge in ordinary room light. The charge will keep it going through the day. When the watch needs a "deep" charge, no more than once a week, you expose it to sunlight for three minutes. It holds a full charge for 48 hours.

MILITARY

MIG-29 FULCRUM
MACH 2.3 INTERCEPTOR

MIG-31 FOXHOUND
MACH 2.4 INTERCEPTOR

SU-24 FENCER
LONG-RANGE
DEEP-STRIKE FIGHTER/BOMBER

MIG-27 FLOGGER
GROUND-ATTACK
FIGHTER/BOMBER

SU-27 FLANKER
MACH 2.3 INTERCEPTOR

SU-25 FROGFOOT
CLOSE-SUPPORT
FIGHTER/BOMBER

BLACKJACK A
LONG-RANGE
INTERCONTINENTAL
BOMBER AND
CRUISE MISSILE
LAUNCHER

Russia's vast new air armada: Good and getting better

Soviet-watchers are watching the skies with increased concern. According to intelligence reports, Russia is in the process of launching the biggest new air armada since World War II. At least seven new combat planes of advanced design are known to be in service already or nearing production. These include three highly sophisticated interceptors—the MiG-31 Foxhound, MiG-29 Fulcrum and Su-27 Flanker; three deadly ground-attack fighter/bombers—the Su-24 Fencer, MiG-27 Flogger and Su-25 Frogfoot; and a huge new intercontinental bomber known as the Blackjack A.

Their significance lies not just in their number, but in their type. In the past, Russian aircraft designers have tended to settle for quantity over quality; now they're going for quality as well. The three new interceptors all have speeds in excess of Mach 2—twice the speed of sound—and possess what is known as "look-down, shoot-down" radar—one of the most advanced weapons-guidance systems in existence. It enables a Soviet fighter to hide undetected at high altitude, spot a target 20,000 to 30,000 feet below it and then fire its missiles straight

down for a kill—without the target even being aware of the attacker's presence.

The MiG-31 Foxhound, designed especially to counter our new Rockwell B-1B bomber, has a reported speed of Mach 2.4, a ceiling of 80,000 feet and a combat range of more than 1,000 miles. Such awesome performance has led Pentagon experts to fear that it might well give our own vaunted F-15 Eagle a run for its money. (The F-15, while slightly faster, is limited to a ceiling of 63,000 feet and an unrefueled range of about 600 miles.)

Also evident is an ominous switch in Kremlin strategy from planes intended purely for home defense to those capable of making aggressive attacks on worldwide targets. The Su-24 Fencer, a long-range, low-level, terrain-following fighter/bomber, is specifically designed to sneak in under radar detection and strike NATO positions deep inside Western Europe. The MiG-27 Flogger and Su-25 Frogfoot, two other new fighter/bombers, have already been spotted attacking guerrilla strongholds in embattled Afghanistan.

Britain's *Illustrious* carrier

Britain's newest antisubmarine aircraft carrier, HMS *Illustrious*, is on her first world tour. Sister ship of the HMS *Invincible*, which launched Harrier jump jets in the Falklands, the *Illustrious* is 670 feet long and displaces 20,000 tons. We boarded her in New York harbor, where she paid a call this spring. On her pocket-size deck was a wing of Harriers and long-range Sea King helicopters. *Illustrious* has a ski jump at the end of the deck for quick Harrier takeoff. In addition to the aircraft, she carries Sea Dart missiles for surface-to-air or ship-to-shore combat. Her newest sister ship, HMS *Ark Royal* is scheduled for launch next year. It will give Britain five Harrier carriers.

PHOTO BY STEVE ESKOW



HMS *Illustrious*, Britain's newest Harrier carrier, visited New York.



One example of Russia's switch to offensive strategy is the Su-24 Fencer (top), a sophisticated, swing-wing fighter/bomber similar to our F-111. Capable of high-speed, low-level attack to avoid radar detection, it's specifically designed to strike NATO targets deep inside Western Europe. Above are two Yak-36 V/STOL jump jets comparable to our Harrier, but with one advantage—they're supersonic.

Editor: Dennis Eskow
Contributors: Sheldon M. Gallager, Jack Hammond, Ida Beck,
Michael A. Fillon, Fran Wengrad Golden, Kevin
Shyne, Jim Peterson, Terence Dickinson, Bruce Most

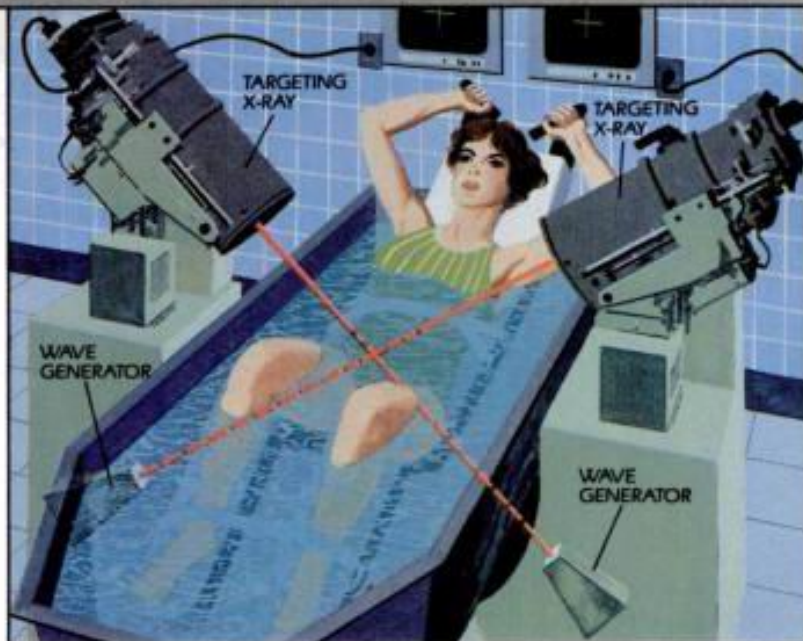
Perhaps the most fearsome member of the new armada is the Blackjack A, a mammoth long-range, supersonic bomber that for the first time gives Russia hit-and-run capability anywhere in the world. Bigger, faster and more powerful than our B-1B, it can also launch cruise missiles from points beyond the reach of our fighter protection.

For those who may think we're spending too much on defense, the following facts are sobering: In the U.S.S.R., military expenditures consume more than 15 percent of the country's gross national product; in the United States, they account for less than 7 percent of the GNP. Soviet fighter production averages 1,060 planes a year. Current U.S. fighter production: less than 500 a year. The implications are grim. Until now, we've enjoyed technical superiority if not numerical superiority. But by the end of this decade we may face the threat of a Soviet air force that is at least equal to ours in quality and still vastly superior in quantity. The Russians may not have caught up quite yet, but they're getting awfully close.



Pencil thin, lightning fast

The U.S. Army Artillery unit at Fort Sill, Okla., is experimenting with a new mobile radar unit that sends out pencil-thin beams to detect hostile weapons in the field. The portable "Fire-finder" unit, developed by Hughes Aircraft, transmits its data to friendly units that return fire.



DRAWING BY DEAN ELLIS

X-ray beams target kidney as wave generators shatter stones.

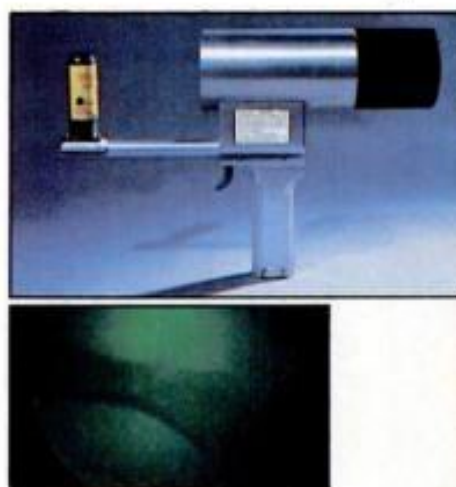
MEDICINE

Kidney stone blaster

Doctors who have tried it say the Lithotripter is as easy to work as the controls of the arcade game "asteroids." But the newest medical machine from West Germany takes care of one of medicine's most serious problems: kidney stones. The device consists of a hydraulic lift that lowers a patient into a bathtub. Wave generators at the bottom of the tub use electrodes to send harmless waves through the water. A pair of X-ray cameras hooked to a computer focus in on the kidney to show the doctor just where to point the waves. The generators send over 1,000 waves during a one-hour session. The waves have no effect on biological organs, but do break up the crystalline minerals that make up the kidney stone. After one visit, the patient reportedly can expel the powder that remains in his or her urine. Tests of the machine are under way this summer at six hospitals in the United States. In early tests, the Lithotripter received excellent grades.

Handy new X-ray unit

The Lixiscope is a handheld X-ray imaging scope that's expected to revolutionize sports medicine. Developed by Lixi Inc., the lightweight device gives off such low levels of radiation that no screening is needed to protect the doctor or patient. A screen inside the battery-powered device gives clear images at the scene of an accident or on a playing field. It was first developed for NASA, which uses a different version to photograph celestial objects.



Lixiscope (top) is a portable, battery-powered X-ray device. It takes images of fractures, such as the one shown above.

ON THE HORIZON

Life On Artificial Islands

BY FRANK P. DAVIDSON
Illustration by John Berkey

The 21st century man-made island shown in this artist's conception would be built 200 miles off the Atlantic Coast. The outer rim of the island would provide space for farming and solar collectors. A nuclear power plant could provide electricity at a distance from the island. Inland, a huge mall would house offices, apartment complexes and warehouse areas. The island would have a supertanker port, a heliport and an airport for small jets and V/STOL aircraft.

ABOUT THE AUTHOR

Frank P. Davidson, co-author of the best-selling book *MACRO* (William Morrow, \$17.95), is chairman of the System Dynamics Steering Committee at the Alfred P. Sloan School of Management at Massachusetts Institute of Technology. He also worked with British and French agencies in the planning of an English Channel tunnel.





Using 1980s technologies, we're on the verge of building our own livable off-coast lands.

Unexpectedly, like a mythological monster, the island rises out of the sea against the disappearing horizon. It appears on no maps. Indeed, just two years ago it didn't exist. A miracle of engineering, some would say. The grand real estate deal, according to others. The 21st century has barely begun and mankind, finding travel to distant lands commonplace, has now gone a step beyond and built new lands. Artificial islands.

We can look ahead to this bold accomplishment of macro-engineering—the building of huge projects—because the technology is already at hand in 1984. Mammoth artificial islands sit in Chesapeake Bay off the Maryland coast and in Japan's Osaka harbor. Scores of ultralarge oil platforms break the horizons of Prudhoe

Bay, Alaska, the Texas Gulf and the Gulf of Arabia. We're building and planning islands at a quickening pace to meet the demands for pristine air, more living space, deep-water ports and oil exploration. New York State is exploring the possibility of building an off-shore tanker port near New York City. Japan has already set aside funding for an island airport in Tokyo Bay, beneath which would coexist offices, apartments, tanker docks and warehouses.

Why not look ahead to the 21st century and an even greater leap in man-made land construction? The island sits 200 miles offshore, far from the smog and traffic of the city and benefiting from the favorable tax treatment of a "free port." Here, new industry can grow at an orderly pace without getting tied down to

ARTIFICIAL ISLANDS

bureaucracy and excessive taxes. Here, the environment can be controlled from the sea bed up. We'll call it Liberty Island.

Connected to the mainland by a multitubed tunnel, the island's mass-transit system brings it closer to the rest of the world than a midtown bus. State-of-the-art roughing pumps keep the tubes virtually air-free. That allows a maglev train system to race above its magnetic track at supersonic speeds. The idea is based on a demonstration in 1982 by Yoshihiro Kyotani of the Japan National Railways. He and his team succeeded in running a full-scale, electromagnetically levitated maglev train 300 mph on a test track. It was just a small leap of the imagination to the supersonic train. Having escaped the friction of a track through levitation, it now also escapes air friction by virtue of the tunnel's roughing pumps.

Laying the transportation tube at varying depths down to 3,000 feet allows the transit system to follow the contour of the ocean bottom, sitting on rock ledges or man-made piers that bob imperceptibly above their anchors. This idea also originated in the 20th century. Submarine engineer J. Vincent Harrington even identified an attractive North Atlantic route for a proposed pipeline.

Liberty Island rises on piers that float and are anchored hundreds of feet beneath the base. Ships can literally pass beneath the island. On one side of the irregularly shaped land mass, a rock ledge beneath the sea permits part of the mass to be supported by polders, large prestressed concrete walls of the type used for Holland's major dikes.



COURTESY MITSUI ENGINEERING



Japanese concept art shows Technoport Osaka (top) as it will look when completed in the next decade. Aerial photo (above) shows portion of the 9-sq.-mi. island already built.



COURTESY SOHIO ALASKA PETROLEUM

Oil-drilling islands such as the Sohio gravel construction in Harrison Bay, Alaska, are the forerunners of large-scale man-made islands. The island, which is made of 1.25 million cu. ft. of gravel, is 350 ft. across. It's built for calm seas.

On one side of Liberty Island sits the world's largest supertanker port. It can accommodate scores of tankers that couldn't get into New York Harbor or Chesapeake Bay. This section is patterned after "Europort," a series of artificial islands linked together off the North Sea. The Europeans began building it island-by-island shortly after World War II.

Like the older Europort, our futuristic Liberty Island brings the ships inside protective walls that keep away the driving sea and fierce winds of occasional storms.

The 21st century island is composed largely of solid wastes from the cities it serves. Safe containment walls of lightweight steel and other advanced materials are used to contain the waste.

Liquid waste, chemically treated at sea, is pumped into Liberty Island's soil as fertilizer, now that its deadly chemical components have been incinerated. On a level just above the shipping, the liquid wastes and the salt air of the sea help farmers grow a bumper crop of legumes.

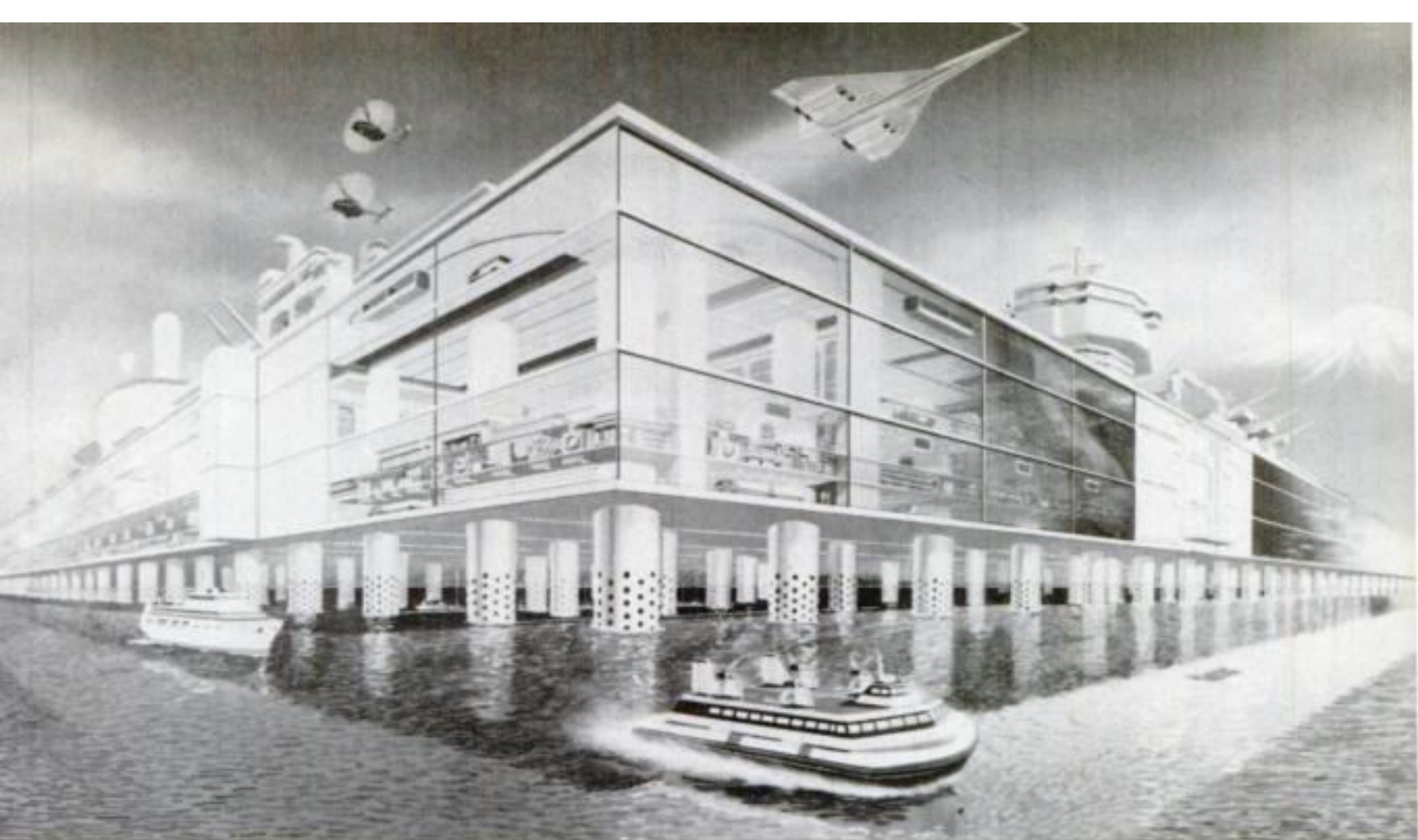
Near the outer edge of the farmland, close to the shore, a fishery, facing incoming ocean currents, uses cranes and nets to farm the carefully husbanded local sea. Indeed, Neil Ruzic's 1980s experiments with man-made reefs in the Caribbean lay the perfect groundwork for such fisheries.

On the next level up, angled away from the farm country to allow maximum sunshine, the real city begins. High-rise office buildings take up a



Artificial Island of Chesapeake Bridge-Tunnel is seen during construction.

COURTESY RAYMOND INTERNATIONAL



Mitsui Engineering concept of Tokyo Harbor Airport Island is based partly on early work of Buckminster Fuller. The island will stand on prestressed concrete pillars sitting on concrete pads that act as "shock absorbers" to keep the structure standing in an earthquake. Because the island will be raised above sea level, boats will be able to pass underneath.

considerable part of the outer periphery. Farther inland, a giant contained city—a super mall of the future—contains stores, apartments, offices, research facilities and a heliport. Atop the entire affair is an airport, where small jets, V/STOL craft and prop-driven planes can land. (Such an airport is part of the plan being funded by the Japan Institute for Infrastructure Development in Tokyo Bay. The Japanese government in 1983 appointed an engineering team to begin designing the island for completion in the 1990s.)

An old idea

Man has been building small artificial islands, or adding on to existing islands, for eons. In Aztec cities of ancient Mexico, causeways and small landfills were the forerunners of the 20th century landfill islands and deep-sea oil rigs.

With the advent of improved construction materials such as high-tech metals and ceramics, and with 20th century overcrowding, man finally had the tools and the drive to go to large-scale artificial lands.

One of the world's most impressive systems of artificial islands sits off the Maryland coast in the Chesapeake Bay. Completed in 1964, the Chesapeake Bay Bridge-Tunnel system was built in three years by Raymond International Builders. The \$200 million island chain links the Delmarva Peninsula with Nor-

folk, Va. Most of the nearly 20 miles of the Chesapeake structure is taken up by bridge trestle structures or tunnels.

Four man-made islands, each eight acres in area, sit in waters 30 to 45 feet deep. The islands rise up to 30 feet above the mean water level so that only the fiercest of storms will carry large amounts of water over the surface. It took 1.5 million tons of sand and 300,000 tons of rock to build each island. Today, they provide approach ramps to the tunnels and service areas located along the lengthy road system. Garages, emergency equipment and tunnel ventilation buildings are on each Raymond island.

As if preparing for the advent of bigger man-made islands, Raymond constructed specially designed low-level trestles of precast, prestressed concrete at a plant built especially for the Chesapeake project. Since then, Raymond has used the plant to build components for seaboard highways. The trestles used on the Chesapeake project have withstood pounding salt water and ravaging winds for 20 years without a substantial sign of damage. Such material is the basis for the polders used to hold up the landward side of our imaginary Liberty Island.

Oil platform experience

The futuristic island will need more than polders to keep it from breaking apart of floating away. On the seaward

side, ocean currents, winds and storms present a tremendous engineering challenge. This is where the oil platform technologies will come into play. Today's oil platforms face challenges from nature such as wind and water damage and risks from the drilling itself. The engineering job is to construct a stable platform that will remain stable even as oil is removed, causing increasing give in the earth holding up the structure.

Oil companies have developed a wide range of platforms for different environ-

(Please turn to page 117)



Concept art shows an oil platform on a conical tower to deflect ice chunks.

COURTESY AMERICAN PETROLEUM INSTITUTE

TECHNOLOGY UPDATE



MILITARY

Coming: Our fast new battle armor

When the U.S. Rapid Deployment Force was first proposed in 1980, nearly everyone agreed it was a good idea, but few seriously believed it would be needed so soon. That was before our troubles in Lebanon, Grenada and Central America. Now all doubts have vanished and the RDF, recently renamed Central Command, is shifting into high gear. Its objective: to develop a lean, tough, hard-hitting strike force that can go anywhere in the world at a moment's notice.

The result is a whole new breed of fast, agile fighting machines that are light enough to be readily transportable, yet heavy enough to deliver decisive firepower. Three of the latest and most lethal are the RDF Light Tank (RDF/LT), the Improved TOW Vehicle (ITV) and the Light Armored Vehicle (LAV). All three can be quickly airlifted into combat by helicopters or small car-

go planes like the C-130, eliminating the need for huge C-5A transports that require long, heavily reinforced runways. They can also be delivered directly to an embattled beachhead aboard the Navy's new air-cushion landing craft (see *Our Fast New Armada*, page 83, Jan. '84).

At less than 15 tons, the new RDF Light Tank weighs only one-quarter as much as traditional tank designs like the mammoth 58-ton M-1. Yet it has virtually the same power-to-weight ratio (24 hp/ton) and can scoot over forbidding terrain at a brisk 40 mph.

Its 75-mm automatic cannon fires 70 rounds per minute, making it, in effect, a large-bore machine gun capable of penetrating all but the heaviest frontal armor on Warsaw Pact tanks. Unlike the flat-firing cannon on other tanks, it can be pointed upward to knock down enemy aircraft. Thus, the RDF/LT is

actually two potent fighting machines in one—a ground-attack tank killer and a highly mobile antiaircraft battery.

The Improved TOW Vehicle, looking like something from another world, fires the deadly TOW antitank missile from an unusual pop-up launcher that can be raised to shoot over an embankment or other screen, while the hull and crew remain safely hidden. The launcher also retracts into the hull so its twin firing tubes can be reloaded from inside without exposing the crew. The ITV weighs 13 tons and can fire two missiles every 40 seconds while traveling at 42 mph.

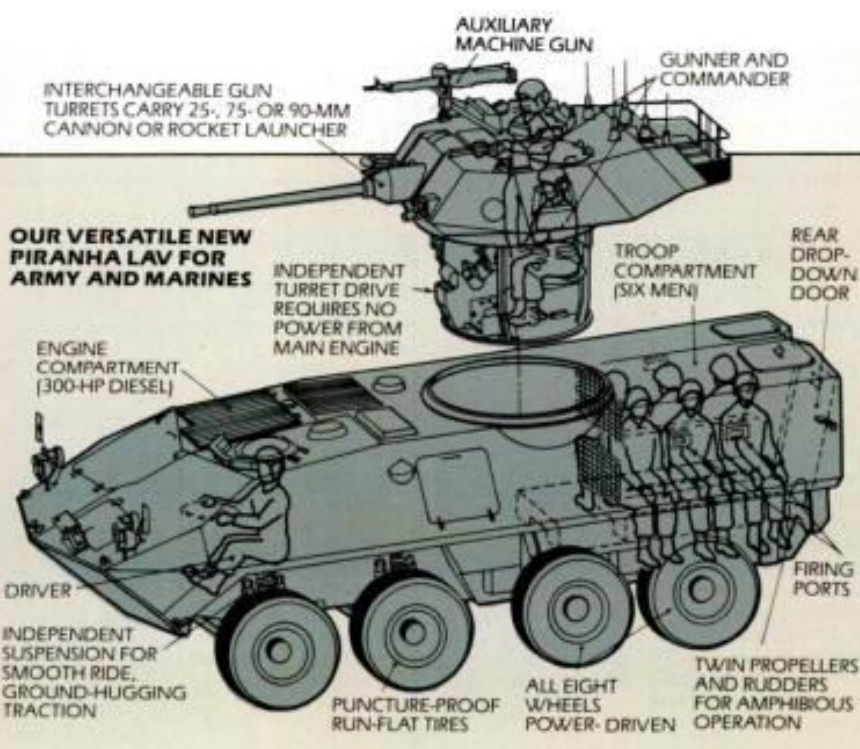
Of the three, the lightest, fastest, and most versatile is the Light Armored Vehicle, also called the Piranha. A multipurpose, eight-wheel-drive, amphibious assault vehicle, it serves as both a high-speed gun platform and an armored troop transport. Interchangeable

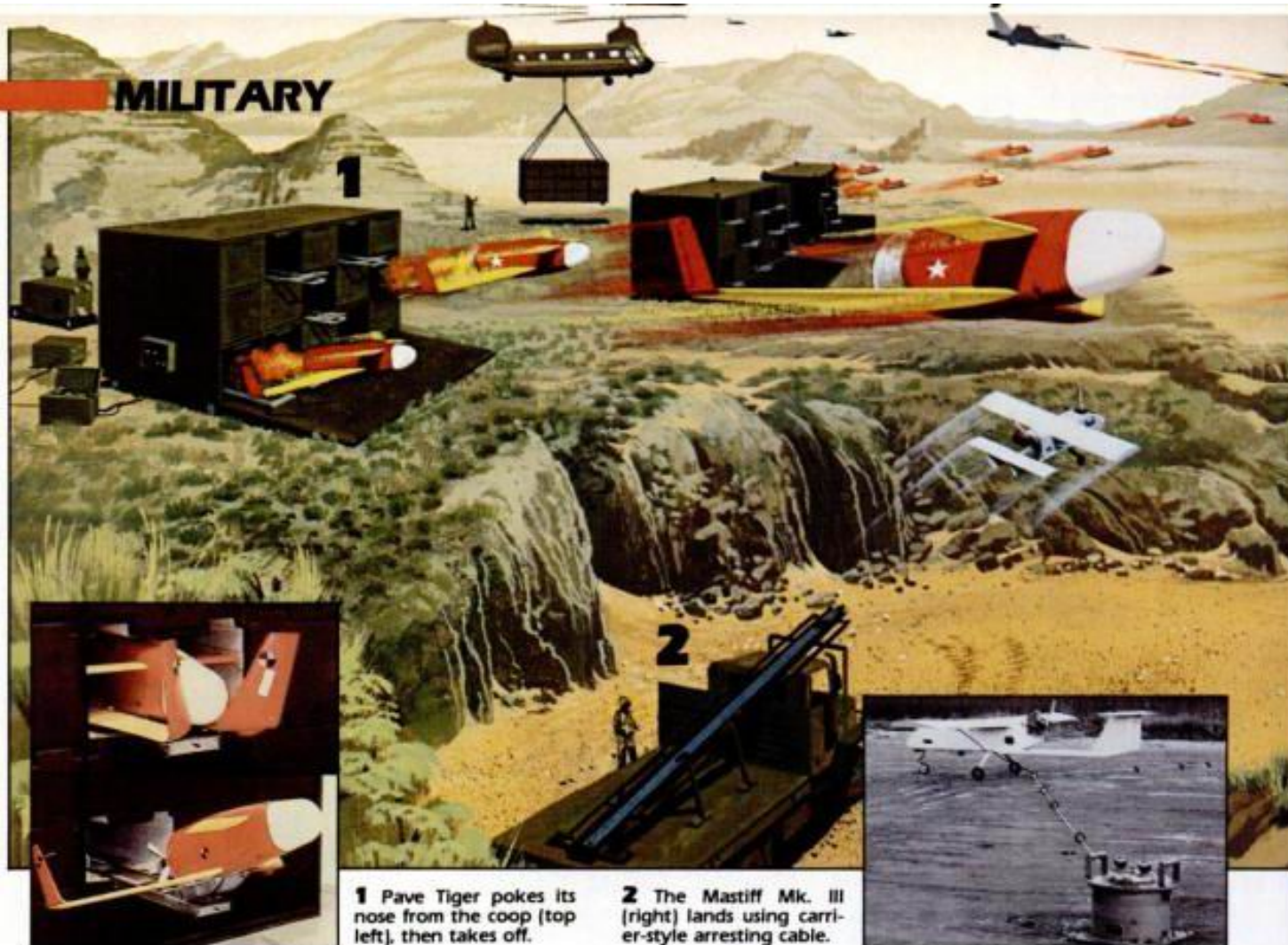


New combat vehicles shown above and on facing page are: 1. RDF/LT with 75-mm cannon; 2. LAV Piranha with 90-mm cannon; 3. ITV with missile launcher retracted for reloading; 4. LAV Piranha with 80-mm multiple rocket launcher; 5. LAV troops debark by rear exit ramp; 6. LAVs in amphibious mode crossing water; 7. RDF/LTs with cannon elevated for antiaircraft use; 8. ITV with TOW missile launcher raised for firing.

turrets allow it to mount cannon from 25 to 90 mm or a vicious 80-mm multiple rocket launcher. Six soldiers, firing through side ports, can be carried in back. To speed their deployment in battle, the entire rear end drops down to form an exit ramp. The LAV weighs 12.5 tons, can exceed 60 mph on land and has twin propellers and rudders for operation on water.

But the real significance of the Central Command's new rapid-response force may lie in what it won't do—it won't employ atomic weapons. By providing us and our NATO allies with a strong deterrent based on conventional arms, it could prevent a confrontation from escalating into nuclear war—and that's the best news.





1 Pave Tiger pokes its nose from the coop (top left), then takes off.

2 The Mastiff Mk. III (right) lands using carrier-style arresting cable.



New unmanned 'fighter planes' save pilots' lives

When the Israelis sought to destroy hidden missile sites in Lebanon's Bekaa Valley, they first sent in small, unmanned reconnaissance drones called RPVs (Remotely Piloted Vehicles). Cheap and expendable, the little winged drones provided electronic eyes to help following pilots spot their targets. They also acted as sacrificial decoys, deliberately drawing enemy fire to flush out its position—all at no risk to human life or multimillion-dollar fighter jets.

Encouraged by their uncanny success, the U.S. Air Force, in conjunction with Boeing, is now studying an even more advanced RPV system known as Pave Tiger. Unlike the Israeli version, used only for surveillance, Pave Tiger RPVs carry explosive warheads and are actually remotely guided,

flying bombs. Up to 15 at a time can be unleashed in flocks from a multiple launcher that looks like an overgrown pigeon coop. Each RPV stores, with wings folded, in a separate compartment. At the push of a button, out it pops, its wings unfold, and off it sails, powered by a tiny prop.

Known as a "harassment drone," the Pave Tiger can bedevil an enemy in several ways: It can attack a target directly if its location is known; it can attract enemy fire, then home in on the enemy's own missile-guidance signals; or it can merely "loiter" overhead for as long as 10 hours, forcing the enemy into inaction just by the threat of its presence. Its engine noise, intentionally loud, can also mask the approach of friendly helicopter gunships.

New threat from a battle-tested jet in the Mideast



Still deadly after 10 years: A Super Étendard on a French carrier.

It's a 10-year-old aircraft that's barely supersonic, but it could mean big trouble for us and our NATO allies. It's the French-built Super Étendard, a carrier-based fighter-bomber that first made news at the Falklands in 1982 when Argentine Super Étendards equipped with deadly Exocet missiles played havoc with British warships.

The latest shocker is that France has leased five of the aging jets to Iraq, known to have her own supply of Exocets. Now Iran is threatening to blockade the Strait of Hormuz, shutting off Persian Gulf oil to the rest of the world, if Iraq attempts to use the planes against Iranian oil facilities. What makes the veteran Super Étendard so devastating is not its speed (less than Mach 1 at sea level), but the fact that it carries advanced all-weather navigation and target-seeking avionics. Thus, it could touch off new tensions in the already turbulent Middle East.

TECHNOLOGY UPDATE

MEDICINE



Doctor takes bone tissue (left) in nonsurgical biopsy. Procedure uses gamma picture (top, right) made through lead ring (bottom).

Bagel biopsy

A plain lead ring is keeping patients with bone ailments from having to undergo some types of exploratory surgery at St. Agnes Medical Center in Philadelphia and at several other institutions. A small amount of "marker" chemical is injected into the patient's vein. A special "gamma" camera then scans the patient, giving a radiological picture of his bones. The ring is placed on the skin, blocking out gamma rays and pinpointing a spot where there is an infection or tumor. The doctor inserts a needle in the center of the ring and draws out a sample of bone tissue. The procedure takes the place of a biopsy.



3 The Peanut flies like a helicopter and makes frightening noises.

Meanwhile, two other new RPVs are also making news. The Mastiff Mk. III, Israel's latest eye in the sky, is an improved version of the type used in Lebanon. Looking like a radio-controlled model airplane, it carries sophisticated surveillance gear, has a range of 60 miles and can remain aloft for seven hours. It's catapulted from a mobile launcher and retrieved by an arresting cable like a carrier jet.

From Canada comes the Peanut, named after its unusual double-ball-shaped body. Under test by the U.S. Army, it combines surveillance with a sneaky harassment twist. Large contrarotating blades, turning around its midsection, enable it to take off and land like a helicopter and also make a lot of noise to let the enemy know it's coming. The bad guys either shoot it down, revealing their position, or they scurry for cover. Either way, the good guys win.



MINEPROOF MINE SWEEPER

Most ships fear to venture into mine-infested waters, but not this new British BH.7 hovercraft. Its soft skirt and air-supported hull are virtually immune to underwater blasts, making it ideal for both mine-sweeping and mine-laying operations. The vehicle is built by Westland's British Hovercraft Div. It can also carry troops safely through minefields.

ENERGY



Cryogenic valve adjusts helium, which supercools the accelerator.

Economical atom smasher

The Superconducting Linear Accelerator at New York's State University at Stony Brook cuts the cost of accelerating atomic nuclei by 30 percent. Normally, the costs run to thousands of dollars per experiment. The secret is a superconducting mechanism in the ring. The Stony Brook accelerator is cooled to minus 450° F. with liquid helium. That reduces electrical resistance to near zero. The accelerator is modular in construction, with 12 elements that can be individually repaired. That eliminates the need to warm up the whole unit to diagnose a problem in one section.



PHOTO BY JEFF HINCKLEY

Chuck Balmer and Avatar greet guests at the door. The 85-pound Avatar uses three on-board processors to perform tasks.



PHOTO BY ROGER BENNETT

Marc Arc's Sir-O-Gate features a Motorola experimenter's board. The user can constantly change inputs to expand memory.



PHOTO BY ROGER BENNETT

Author Tom Carroll works on his next robot, called Ultima, in his shop. With him is Squirt, which is a 3-foot-high android.

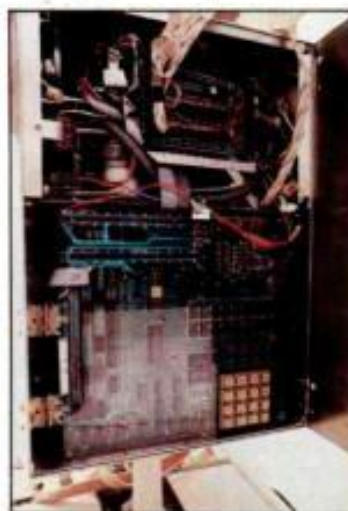
The Smartest Homebuilt Robots

America's hottest new robots are being constructed in the workshops of amateurs who have a vision for the future.

BY TOM CARROLL; Illustrated by Pat Ruggero



The best parts of a great robot



Jim Hill's robot, called Charlie, can't really read *Popular Mechanics*, as shown in the photo (far left). But it can "sense" walls electronically and avoid running into them. The robot is being rewired to coordinate hand movement with sensing. The processor unit (left) controls the 200-pound robot. The arm and hand (above) are able to grasp and lift heavy objects.

PHOTOS BY BRIAN WOLFF

The guests have arrived and are standing about your host's elegant oceanside home, exchanging the social chit-chat of the day. Suddenly, the host excuses himself, taps on the kitchen door and says, "Sam, you may serve the hors d'oeuvres now."

The door opens silently and out rolls a shining, squat robot deftly carrying a tray of olives and mini-sandwiches. The silver mechanical servant, reminiscent of R2D2 of *Star Wars* fame, glides among your friends. Its synthesized voice coaxes the guests into serving themselves from the tray, but the robot also takes orally-recognized orders for food and drink. Then the host's faithful servant retires to the kitchen to prepare crab.

How far from reality is this picture? The finished product may be some years away, but the technology is with us today. And, while there are about a dozen companies producing kits and ready-built robots, the state-of-the-art in home robots is being accomplished by the "scratch" robot builders.

Jim Hill of Covina, Calif., is somewhat typical of the home robotics experimenter. A parts department manager for an automobile dealership, Hill handcrafted his second robot, Charlie, from auto power-seat motors, aircraft flap actuators and numerous surplus items. The 200-pound, computer-controlled robot has a level of sophistication unequaled by its industrial counterparts. Constructed over four years, Jim made his robot using basic shop hand tools. At



Wings of the future

The U.S. Air Force is always dreaming up exotic new shapes for future aircraft. The two concepts shown here, both for long-range strategic bombers, are straight out of the 21st century.

The plane above right has a swiveling wing that swings crosswise for low-speed landings and takeoffs. For high-speed flight, the wing retracts into the top of the fuselage (center) to reduce drag and the plane cruises solely on lift produced by its broad, flat underbelly.

The other design features forward-swept wings and canards for improved lift and maneuverability. Both concepts were developed by Rockwell International.

MILITARY



OFFICIAL U.S. AIR FORCE PHOTOS.

Tomorrow's bombers? They just might be. Both of these futuristic concepts are the work of Rockwell International, already noted for development of the mighty B-1B strategic bomber.

GIs get back an old friend

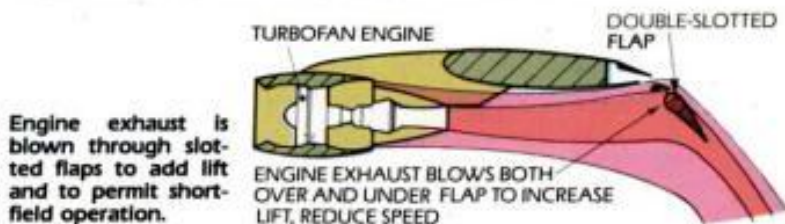
Remember the old Browning Automatic Rifle of World War II? Now, for the first time since the BAR was abandoned, the Army and Marines are adopting a similar weapon. Called the MINIMI, it's light enough to be handheld, yet fires up to 1,000 5.56mm rounds a minute from a clip-on, belt-feed magazine. It's made by the Belgian firm Fabrique Nationale Herstal.

New BAR replacement can be fired from hip or on a tripod with scope sight.



Getting cargo where it counts

The problem with giant military cargo planes like the C-5A is that they require long runways and can't deliver supplies directly to frontline battle areas. Now, the C-17, a new STOL-type transport, can drop an 86-ton payload—almost as much as a C-5A's—into airstrips as short as 3,000 feet. Its secret lies in its blown wing. Exhaust from its four powerful turbofan engines is blown over and against huge double-slotted flaps, increasing low-speed lift to shorten landing and takeoff distance. Developed by McDonnell Douglas, the C-17 can thus fly troops, tanks and other heavy equipment right into battle.



New C-17 can deliver a mechanized force right to the front lines.

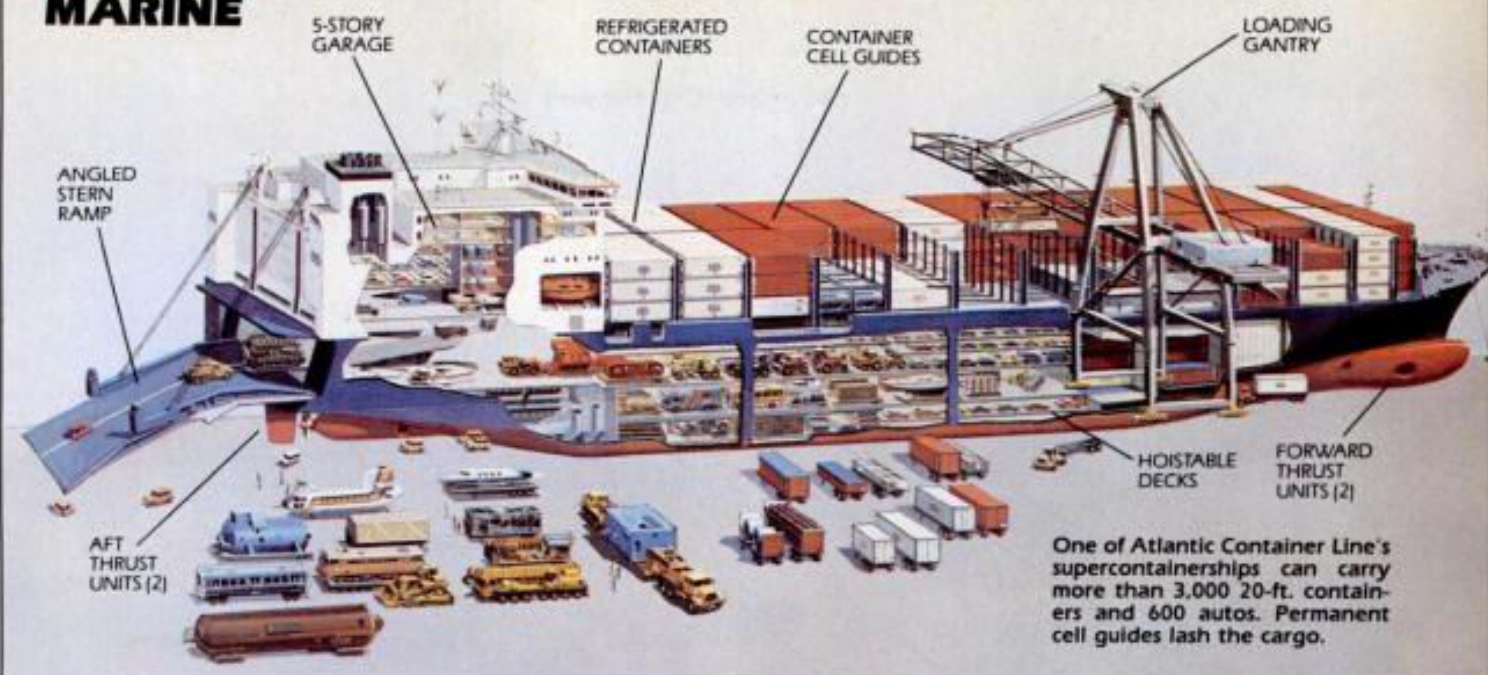
Frozen bird to go

Earlier this year, the Marine Corps' newest jump jet, the Harrier II, went through two months of harrowing weather. It faced 60-below temperatures, 46 mph winds and layers of ice formed on its wings. It all happened in a McDonnell Douglas test hangar in St. Louis. The Marines say the new Harriers will be deployed later this year.



McDonnell Douglas Harrier II undergoes severe weather test.

MARINE



Giants of the sea

Atlantic Container Line is launching a five-vessel fleet of supercontainerships, the container equivalent of supertankers. The 820-ft., 37,000 deadweight-ton vessels can house the equivalent of 2,000, 20-ft. containers and 600 automobiles in the stern structure. Permanent cell guides on the weather decks can accommodate the equivalent of almost 1,500, 20-ft. containers that fit snugly within the guides. Thus, lashing of

cargo will become an extra precaution procedure rather than the only way to hold down cargo.

An angled stern ramp will allow crews to load and unload containers and cars at the same time. In transit, the cars are stored in a five-story garage, where they will be protected from the salty air. Forward and aft thrust units will allow for easy steering to dock.

The supercontainerships will make all current container vessels obsolete by the 1990s.

INVENTIONS

Computerized device has a sense of smell

Below decks, any good-sized ship collects potentially poisonous or volatile chemicals in the ambient air. Argonne National Laboratory researcher Joseph Stetter and his team have developed a computer that can sniff out chemicals, alerting the crew to any impending danger. The 15-pound Argonne sniffer is a tube connected to a microprocessor. As air passes into the processor's test chambers, sensors analyze its chemical and combustion characteristics. With the new system, thousands of lives will be saved by preventing explosions at sea.

Crewman waves Argonne sensor tube below decks (top). The air is evaluated in computer chambers (bottom).



New rotor is very attractive

The Mag-Lev concept propels a train suspended above a magnetized track so it's pulled along on a cushion of air, eliminating friction and producing high speeds and efficiency. British researchers are now applying the concept to a new high-tech rotor for generators and other machines. The rotor cylinder rides inside a magnetized housing. By computer-switching the charge of the magnets around the cylinder, it turns at breakneck speeds with almost no friction. When the rotors are available in five years, they'll improve by 40 percent the efficiency of all machines that use them.

MILITARY



Flying torpedoes fool subs

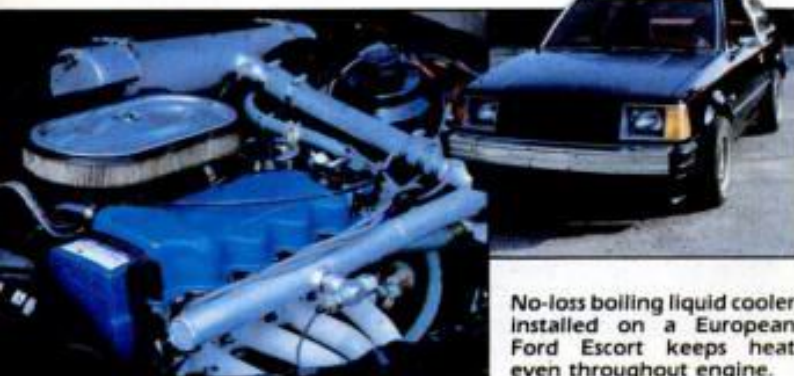
Trying to hit an enemy submarine with a conventional underwater torpedo is tricky because the sub often has time to detect the oncoming torpedo with its sonar and get out of the way before it strikes. Alerted to the threat, the sub can then turn its own torpedoes on the attacker.

With a new airborne torpedo delivery system now available, the enemy sub has no knowledge of the torpedo's presence until it's too late to avoid it. The attacking ship launches the torpedo inside a rocket-powered drone that carries it out over

the target, then releases it on a preprogrammed signal. The torpedo floats down attached to a parachute until it enters the water. Then, it jettisons the chute and homes in on the sub so fast that the enemy has no chance to get away.

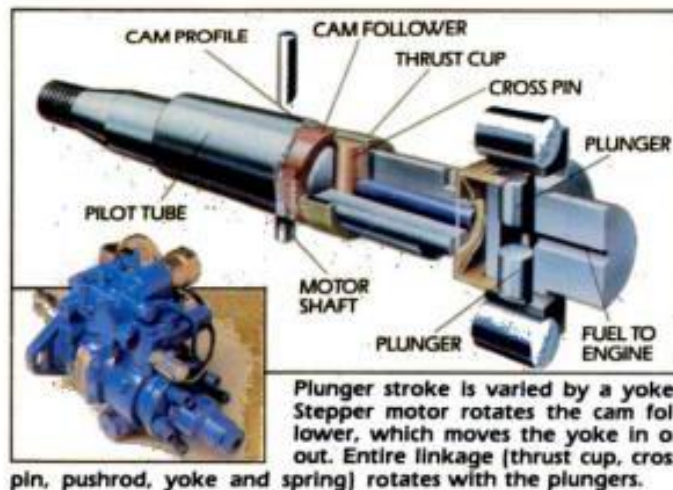
Another advantage of the airborne delivery is that it allows a ship to stand off at a distance and attack a hostile sub far beyond the effective range of the sub's torpedoes, thus making it impossible for the enemy to strike first. Called the Ikara, the system is made in Australia and distributed by British Aerospace. It's designed to handle a wide variety of torpedo types, including the U.S. MK46.

AUTOMOTIVE



Technology for cooler heads

Conventional pressurized circulating liquid automotive cooling systems cause front cylinders to run cooler than rear ones. Bubbling of the coolant sets up localized hot spots that induce knock and cause emission levels to rise. Now, National Technologies has patented a no-loss boiling liquid system that shunts boiling coolant to a condenser, where it returns to the liquid state and flows back into the water jacket. The Evans Process cooling system thus transfers heat quickly, keeping the temperature uniform throughout the engine.



Diesels go electronic

Electronic control of fuel delivery has so far been utilized on gasoline auto engines only. But Stanadyne's new electronically controlled fuel delivery unit is built for diesels. Sensors read engine rpm, piston position and other operational factors to tell the computer when to activate a pump stepper motor, which injects fuel into the cylinder. The system allows more precise fuel metering than conventional pumps. GM will introduce the system in 1986.



General Dynamics E-7 (facing page) gets vertical lift from downward rush of compressed air through ducts in wing. Duct doors, shown open here, swing closed for forward flight. McDonnell Douglas 279-3 (above) uses thrust-boosted version of famous four-nozzle Rolls-Royce Pegasus engine that powers current Harrier jump jet. Nozzles tilt down for vertical lift, up for forward thrust.

Landing). While it will be capable of landing vertically, it will make use of a short takeoff run to permit the carrying of greater payloads. For vertical lift, it will draw air in through auxiliary ducts in the top of its delta wing. This air will then be compressed and expelled downward to produce upward thrust. For forward flight, the ducts will be closed and the plane will operate as a conventional rear-thrust jet.

The McDonnell Douglas Model 279-3, shown in the artist's impression at right, above, is an advanced canard-winged configuration designed around the same four-nozzle Pegasus

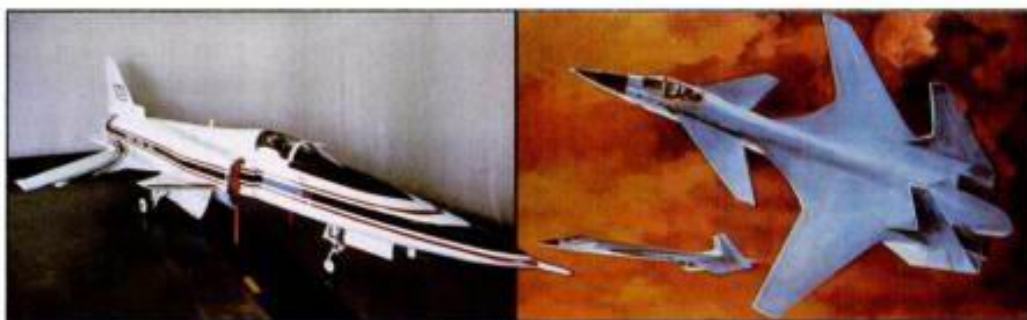
engine used in the current subsonic V/STOL Harrier, but with added combustion chambers to provide supersonic thrust (see *Coming: Jump Jets That Break The Sound Barrier*, page 59, June '84). Like the Harrier, it will be capable of vertical takeoffs and landings, but will have twice its speed and payload.

Vectorable engine nozzles—exhaust ports that tilt up and down to change the direction of thrust—will be used by both fighters not only to shorten takeoffs and landings, but also to increase their maneuvering agility in combat. Both prototype planes could be operational as early as 1990.

Fighter for the future

Grumman's exotic new forward-swept-wing X-29A (near right), the first government-backed experimental fighter in more than a decade, has made its public debut and will soon begin flight testing.

The radical front-swept wings, not practical on a supersonic aircraft until the recent advent of high-strength composites, offer many known aerodynamic advantages over conventional aft-swept wings. Because of better airflow control, they increase lift, reduce drag,



Grumman's X-29A (left) and futuristic concept (right) both employ stubby canards as well as forward-swept main wings. Canards act as elevators, increase maneuverability and improve low-speed control.

save fuel, lessen the danger of stalling and greatly improve combat maneuverability.

Expected to cost up to \$140 million, the X-29A program is jointly funded by

Grumman and DARPA, the Pentagon's Defense Advanced Research Projects Agency. At far right, above, is a Grumman concept for an even more radical future ver-

sion with forward-sweeping tail fins. The X-29A may spawn a whole new generation of forward-swept-wing aircraft—not only military, but commercial as well.



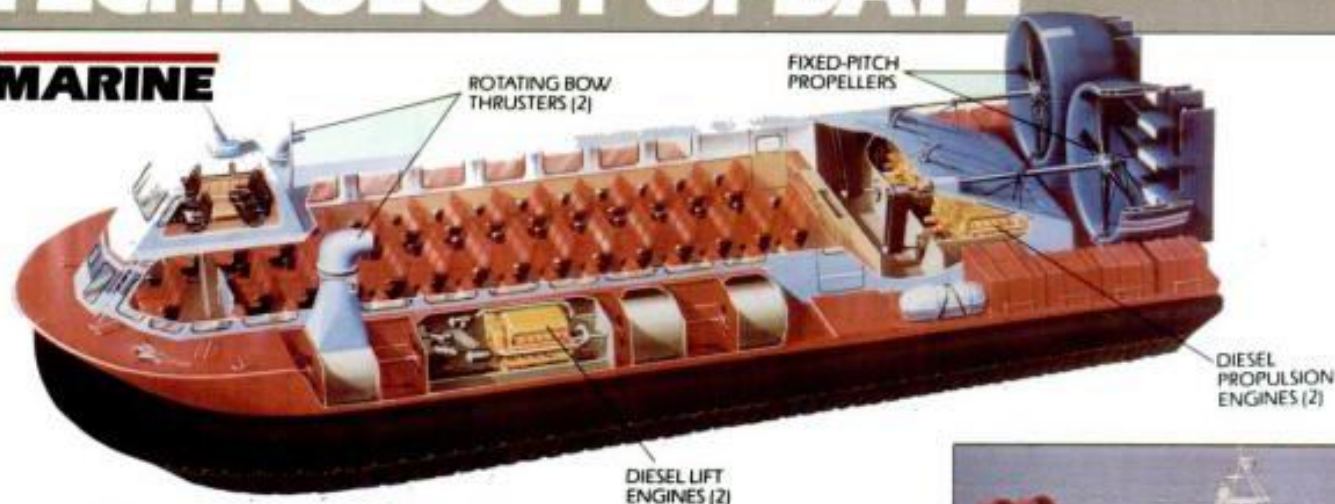
Oops! Your tail is dragging

Ever wonder if the tail of an airliner can hit the ground as the plane rotates steeply for takeoff? Well, see for yourself. The rare sight at left is of Boeing's new 737-300 jetliner deliberately dragging its tail on the runway as it attempts a low-speed takeoff during FAA certification tests.

The tests, known as Velocity Minimum Unstick measurements, determine the slowest takeoff speed that will still permit an aircraft to become safely airborne. The tail, protected by a wood skid, scrapes the pavement due to the low acceleration. But don't worry, folks, it only happens in tests.

TU

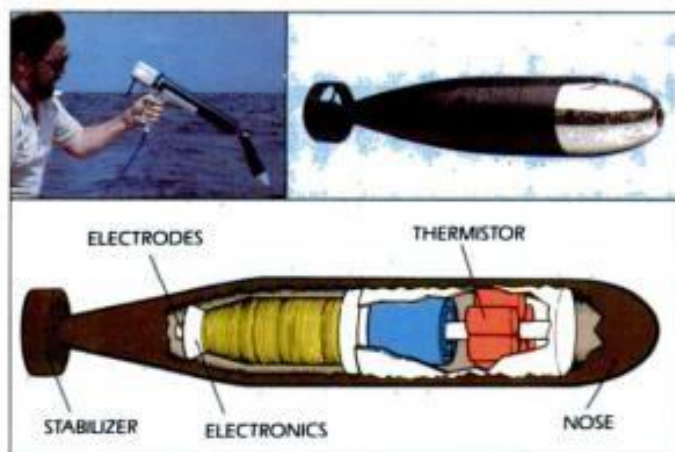
MARINE



New hovercraft replacing airliners

British Hovercraft's new AP-188 ferry has begun carrying 100 passengers per trip using new technologies that may keep a troubled airliner flying. Scandinavian Airlines System had watched its Copenhagen, Denmark, to Malmö, Sweden, business dwindle from 200,000 passengers in 1972 to 40,000 in 1983. Last year, SAS instituted the Hovercraft Service across Öresund Sound, a 17-mile trip that takes 45 minutes. Break-through designs made the switchover possible. A new, low-pressure skirt design has increased payload capacity by over

50 percent. Four new 450-hp Deutz diesel engines provide both lift and propulsion. Two provide power to four centrifugal lift fans and two drive the craft's flexed propulsion propellers. A pair of rotating bow thrusters help steer the vessel for quick entry into its docking facilities. Early reports are that SAS took over 100,000 passengers in 1984. SAS is considering designs for 150- and 200-passenger hovercraft.

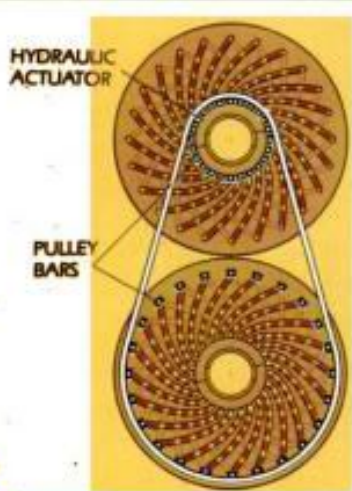


It takes a fish to catch a fish

Hunting schools of oceangoing fish often involves bringing in big survey craft that drag water-testing devices behind them. Salt content and water temperature tell the fleets where to find the fish. It's an expensive proposition. But a new disposable depth probe developed by Sippican will eliminate those costs starting this summer. The torpedolike probe is fired from a handheld air gun. It drops into the ocean and broadcasts an electronic signal down to 200 feet. A thermistor measures temperatures as the torpedo submerges. A pair of electrodes measures salt content. The torpedo has a stabilizing rudder and hard aluminum nose. Its preprogrammed path of travel is fed to the stabilizer by a tiny microprocessor inside the nose. The Sippican probe was tested by the Office of Naval Research in 1982, and will search for lost or hidden submarines.

AUTOMOTIVE Smoothest transmission yet

Several European automakers have been experimenting with Continuous Variable Transmissions over the past two years. The CVTs change a car's gearing in hundreds of steps rather than three, four or five as we are accustomed to have in autos. The problem with CVTs has been a slight lack of smoothness in the ride as the car gears up and down automatically. Designer Emerson L. Kumm says he has licked that and other problems with his new CVT. The Kumm CVT runs a flat Kevlar belt on two variable diameter pulleys. The diameter of one pulley decreases while that of the other increases, continuously changing the input-to-output speed ratio. The belt rides on a number of flat pulley bars that move in and out under the hydraulic actuator's power. The Kumm CVT may be in American cars by 1987.



Computer car

We test-drove the Buick Riviera CRT, which will be on the market in 1986. The car sports a computer screen that will eventually eliminate 80 buttons and dials on the dashboard. Powered by five computer modules, the CRT dashboard screen keeps controls in one place.

SPACE

ILLUSTRATION BY ALAN GUTIERREZ



Jupiter probe enters final test phase

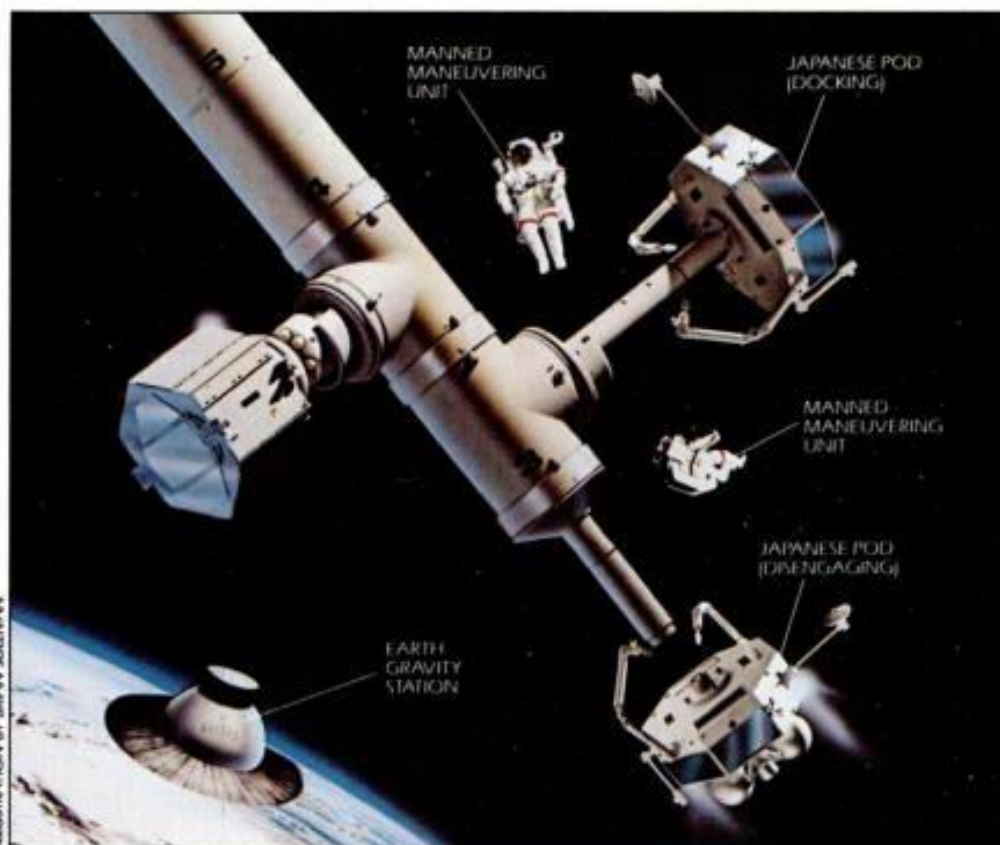
Jupiter is one of the most widely photographed and observed bodies in the heavens. But scientists know little about what goes on inside its gaseous and dense atmosphere. Late next year, the veil is expected to be pierced when America launches the Galileo project.

The Galileo package will take two years to fly to Jupiter on a Titan rocket. When it arrives, an orbiter will begin to circle the planet. Then, a sensor package will be parachuted in through

the large "eye" of Jupiter, a red cloud that is a permanent fixture on the planet's surface. Because Jupiter's gravity is almost $2\frac{1}{2}$ times that of Earth, and its atmospheric pressure is dozens of times greater, the package is expected to self-destruct before it can reach the surface. But, on the way down, it will sense the chemical makeup of the Jovian atmosphere. It will broadcast video images and computer data to the orbiter, which will relay them to Earth.

Station adjuncts

As American aerospace companies work on their designs of the space station, space agencies from other countries and from smaller American firms are coming up with proposed add-ons. Japan's Ministry of Trade and Information is proposing to add a small manufacturing and research pod to the station. The 8-foot-wide circular pod would be Shuttle-launched and could be rocketed back to a Shuttle. Its arms would work with men in Manned Maneuvering Units to perform experiments outside the station. Inside, the pods would be used to manufacture silicon chips automatically. Meanwhile, Natural Energy Systems of Florida has proposed construction of a lightweight flying saucer that would spin in orbit alongside the station. Astronauts could enter the mini station to stand in simulated Earth gravity.



Astronauts maneuver to Japanese space pod as Earth gravity station follows space station in orbit.

Nimble jet

Fighters in wartime must be able to operate from runways shortened by bomb damage. A modified McDonnell Douglas F-15, fitted with movable engine nozzles and canard mini wings, will soon determine just how small a runway space a jet will be able to land and take off in.

Tilted downward, the nozzles produce upward thrust which, along with added lift from the canards, reduces landing and takeoff distance to as little as 1,000 feet.

Also on the way is a head-up display (inset) that will show a pilot how much landing room he has between bomb craters.

MILITARY



Modified F-15 will land and take off in 1,000 feet, a fraction of the mile or more normally required. Head-up display (left) tells pilot if he has room to land on bomb-cratered runway.



Flying blind

Future combat helicopters may fly into battle blind. To test out this radical concept, Boeing Vertol has rigged a chopper with two complete cockpits, a normal one in front and a hidden one in back. A safety pilot sits up front, but the real pilot occupies a windowless compartment surrounded by TV screens (inset). Displayed on the screens are instrument readings, navigation plots, target coordinates and video views of the terrain ahead, even in total darkness—more information, in fact, than a pilot could ever acquire using his own eyesight alone.



Big jets get a big lift

The cumbersome-looking engines above are actually designed to give heavy cargo transports greater lift and agility. Mounted above the wing, they blow their jet exhaust across the top of the wing, generating added lift. Called a blown wing, the system increases a plane's payload and enables it to make steep, STOL-like landings and takeoffs in fields too short for conventional transports.

At bottom is Russia's twin-jet An-72, which can land and take off in less than 4,000 feet. At top is a four-engine Japanese version requiring only 2,370 feet.

How to make a missile miss

Heat-seeking anti-aircraft missiles have one-track minds. To score a hit, they must be able to lock onto a plane's infrared radiation. Now an ingenious new Infrared Countermeasures (IRCM) system prevents this, making an aircraft virtually invulnerable to enemy missiles of the heat-homing type.

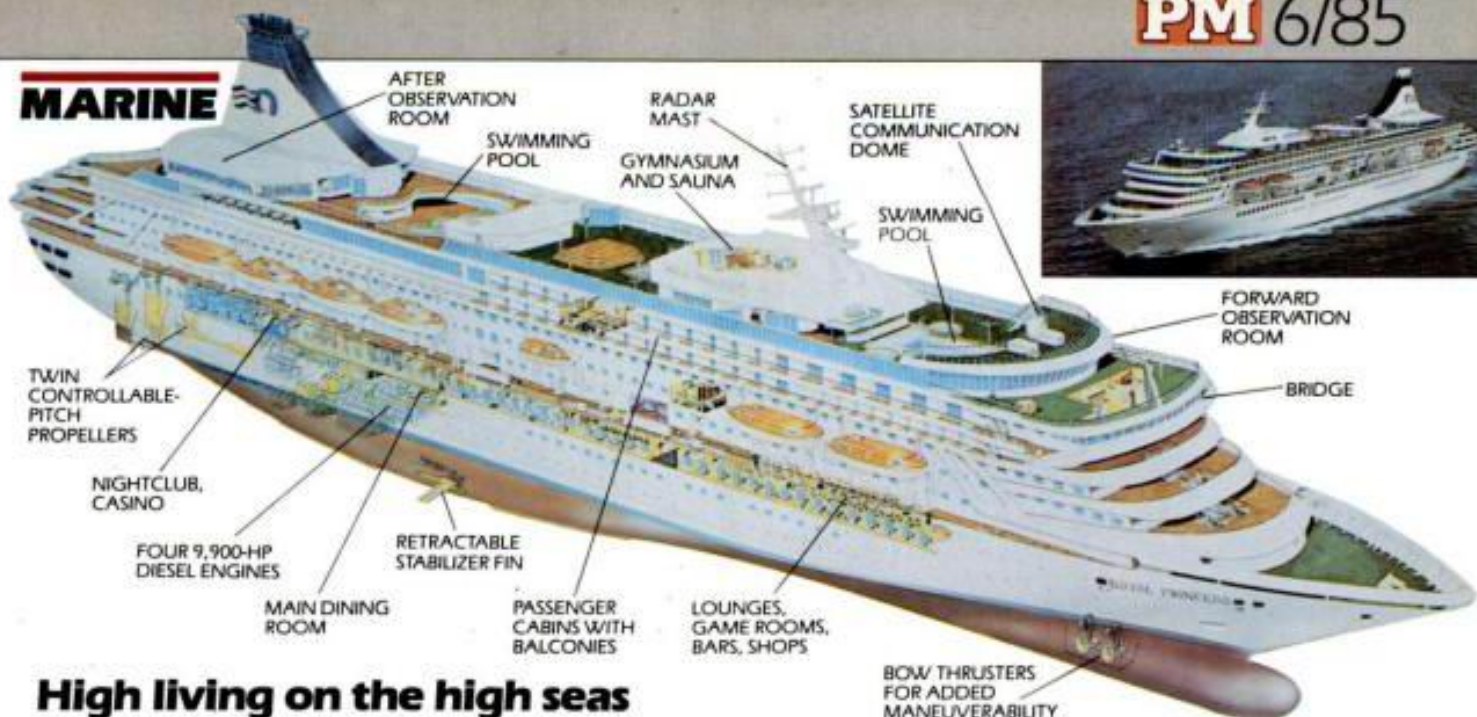
The threatened aircraft sends out decoy jamming signals so similar to those processed by the missile's own tracker that the missile can't make up its mind which signals are the right ones. It becomes confused and flies off harmlessly in another direction, missing its target.

The IRCM system was developed by Loral Electro-Optical Systems of Pasadena, Calif., and is being adopted by both the Navy and Air Force.

TU



MARINE



High living on the high seas

Ever go on an ocean cruise and get stuck in a windowless cabin with no view of the sea? You won't find this aboard the glamorous new *Royal Princess*, the first cruise ship to have no inside cabins. All cabins are on the outside with big picture windows, and some even have their own private balconies. To make this possible, the ship's utilities are concentrated in a central core, leaving the outside spaces for staterooms.

You won't be bored either. Among the ship's many creature comforts are four swimming pools, a gymnasium with sauna, two theaters, a library, nightclub, casino and numerous dining facilities, game rooms, shops and bars. The 758-foot, 45,000-ton luxury liner accommodates 1,260 passengers and a crew of 500. It was built by Wartsila, a prominent Finnish shipbuilder, and will be operated off the West Coast by P&O Cruises.



New life at sea

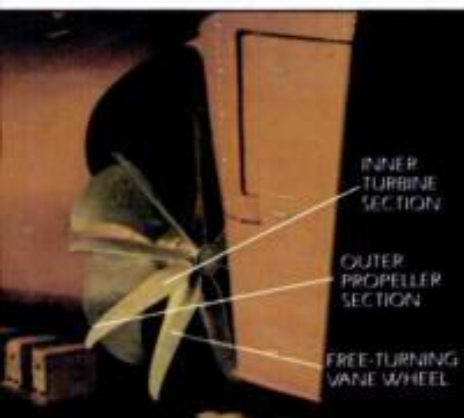
Workers trapped in a submerged vessel or oil rig have to be rescued and decompressed immediately to avoid the bends. Rescue is easy, but decompression is usually a problem if more than two divers are rescued. Britain has come up with a solution: It's a 30-foot-long, reinforced-plastic, pressure rescue vessel. It can rescue up to 70 men at once.

Wasted power put to work

To push a ship forward, its propeller must also push a lot of water backward, wasting energy. Now a multibladed auxiliary propeller, turning freely behind the ship's regular propeller, is putting this energy to work. At its center, the blades are shaped like a turbine's, while at the tips they're shaped like a propeller's. Thus, it's driven like a turbine by the backward flow of water, at

the same time functioning as a propeller to convert the lost energy into added thrust.

Invented by German Prof. Otto Grim, the device reduces fuel consumption by as much as 13 percent. It's being installed on cargo vessels by Bremer Vulkan.



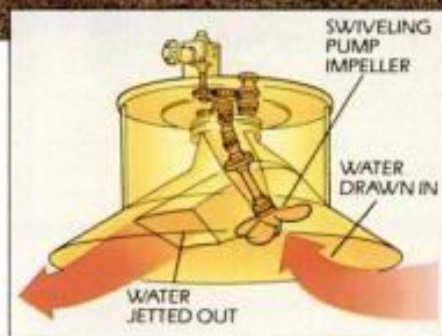
INNER TURBINE SECTION

OUTER PROPELLER SECTION

FREE-TURNING VANE WHEEL



Completely recessed in bottom of hull, water-jet drive can't foul on underwater obstacles. It can be installed as a conventional stern drive or as a bow thruster for added maneuverability in tricky waters. Screen keeps out debris.



SWIVELING PUMP IMPELLER

WATER DRAWN IN

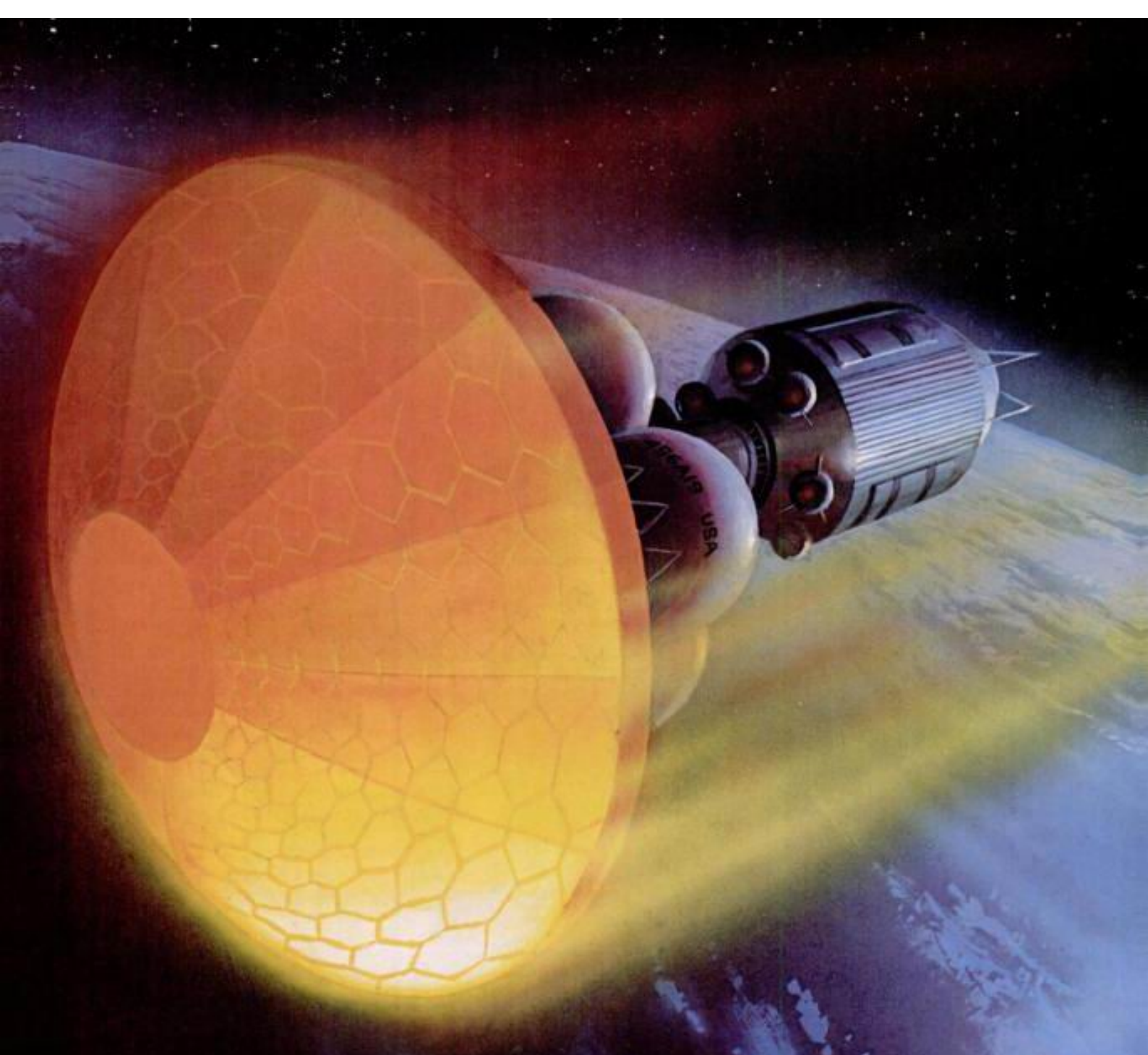
WATER JETTED OUT

Jet drive for tricky waters

Vessels operating in very shallow waters face the risk of damaging their propellers on obstructions or running aground because of insufficient maneuverability. Now, an ingenious water-jet drive solves both problems. A pump draws in water through an inlet and discharges it under pressure through an outlet, producing a powerful jet stream. The entire unit rotates 360° so it can turn a ship sharply in any direction, push it sideways, even provide reverse thrust for braking and backing.

The German-designed system, called Cone-Jet, is distributed here by Schottel of America Inc., Miami, Fla.





NASA's Next Spaceships

NASA's chief looks into the immediate future and sees two new spaceships to enhance space station commerce.

BY JAMES M. BEGGS, Administrator,
National Aeronautics and Space Administration

The time: 1997. The place: 22,300 miles above the Earth. A stubby cylinder about 4 meters in diameter, bristling at one end with a variety of antennas and instruments, and at the other with a powerful rocket engine, pulls into a parking space. It gently deposits its cargo—a communications satellite. Then, with a burst of rocket fire, it begins a return trip to its home base, a manned Space Station, orbiting about 300 miles above the Earth. Another routine working day has begun.

Indeed, for the six-person crew aboard the Space Station, the launch and return of the Orbital Transfer Vehicle is only one of many tasks they will perform over the next few hours. Twenty-four hours later, after 16 orbits of the Earth, 16 sunsets and 16 sunrises, another day in space will begin. The men and women aboard the Space Station will have new challenges and new work inside and outside their orbital home.

The workaday world of space, only a few years off, will be busy. It will be productive. And it will be exciting. We already are getting a glimpse of that world, and of the infinite variety of activities that can and will take place there, when people will live,

PM ILLUSTRATION BY ALAN GUTIERREZ



work and learn in space, not just for days at a time, but on a permanent basis.

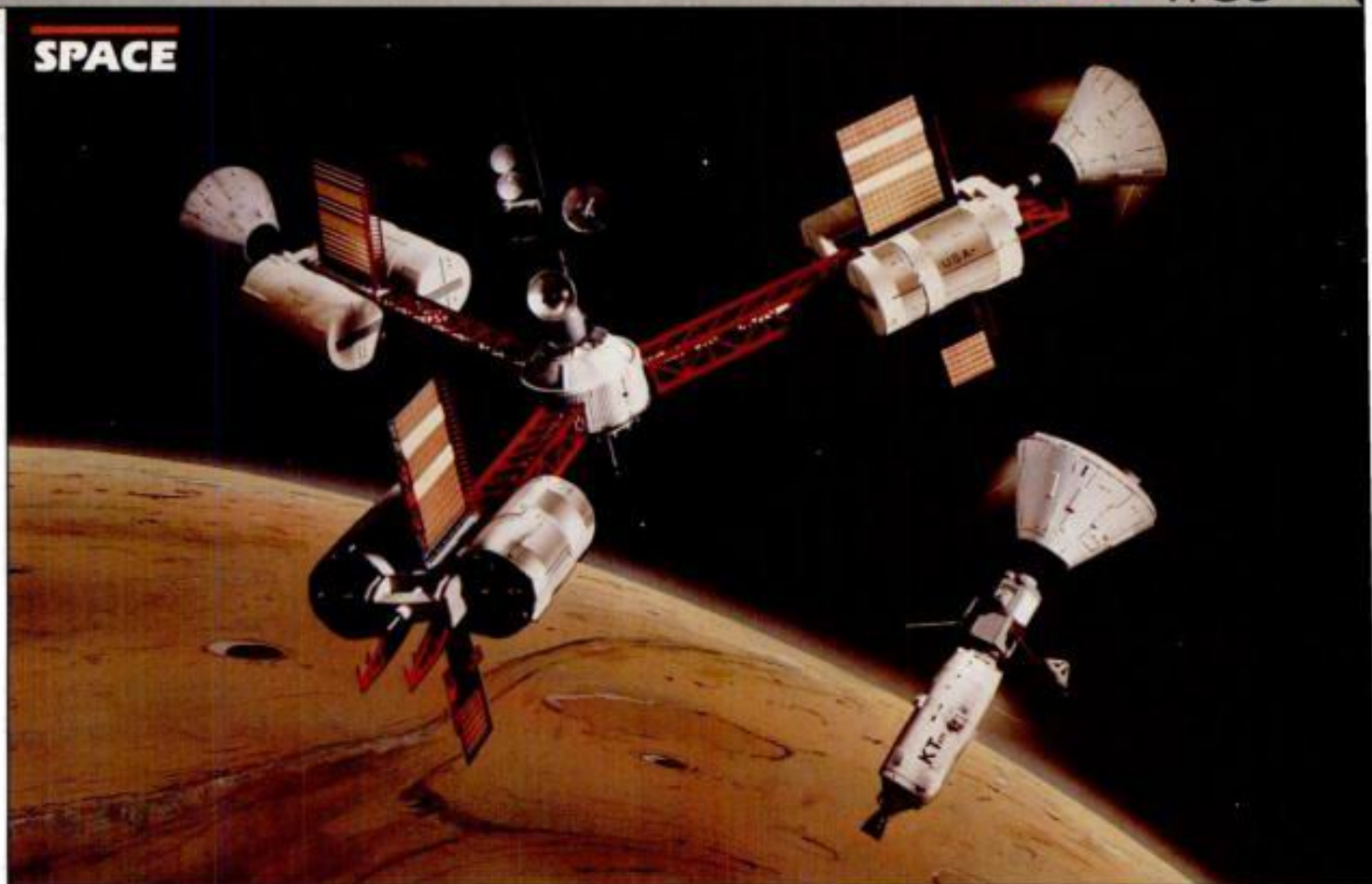
Within the coming decade, we will begin to construct a permanently manned Space Station in near-Earth orbit. Last year, the world got a preview of what can and will be done in space, routinely, when the Space Station is in operation.

In April, astronauts retrieved, repaired and redeployed the Solar Max Satellite, a scientific spacecraft designed to study the Sun. In October, they successfully completed a satellite refueling experiment designed to demonstrate that satellites can be refueled in orbit. And in November, they completed a dra-

Its heat shield glowing, an Orbital Transfer Vehicle (facing page) carries a damaged satellite back from orbit. Meanwhile, an Orbital Maneuvering Vehicle delivers a satellite high above the Space Station. Both new spaceships will be in service by the turn of the century, after the Space Station becomes fully operational.

© NASA

SPACE



PM ILLUSTRATION BY BRIAN SULLIVAN

To Mars in ships

More than 100 scientists and engineers have been talking at meetings this past year about a new American mission to Mars. NASA is just beginning to do studies on a manned mission to the red planet. But the professionals meeting independently this year under the auspices of the Planetary Society, American Astronautical Society and National Space Institute have decided to get ready for a full-bore push for exploration of Mars. Several aspects were discussed, but the most exciting was agreement on what Mars exploration ships will be like.

The scientists agree that a multiship Mars mission can be launched aboard a specially designed super-shuttle by 1995.

As the vehicle approaches Mars, its last stage would separate into five units. A central spherical unit will serve as the command module, where a small crew would operate Earth communications and other equipment. Each of the remaining units would serve as landers or orbiters. Each vehicle would carry a crew of four to and from the surface of Mars or on orbit around the planet. NASA officials say they are studying the proposal and will comment on it early next year.



PM PHOTOS BY TALLAT MOHAMED

Sneaky sports devices

The newest lightweight tennis racket is Kneissl's White Star Aero. The graphite and Kevlar racket is extremely lightweight. But the new technology is in its beveled frame. The bevel makes the racket aerodynamic so its enlarged head doesn't slow the player's swing. Also for sports technocrats is Spaulding's Tidal Wave bat. The bat nub unscrews so the hollow aluminum bat can be filled with water to adjust its sweet spot.

Beep beep and you're out

National League spring training camps this year had noisy outfielders. They were experimenting with Mizuno's new outfield screen, designed to save the careers of baseball players. The screen uses radar-like sensors to pick up an outfielder as he approaches a fence. When the computers detect a human approaching, a beeping sound comes from the gate warning the player of the fence's proximity. The closer the player gets, the louder and more frequent are the beeps. The \$20,000 system is already in use in Japan, and may appear in American baseball by next season.





BREAKING THE SPEED BARRIERS

On land, sea and air and with or without a machine, give man a barrier and he'll break it.

"Thunder is great. Thunder is awesome. But it's lightning that does all the work."

—Mark Twain

They push through the water with such earthshaking power that few call them by their real names. Officially, they're hydroplanes, racing boats that leave the surface of the water, spewing rooster-tail plumes 100 yards behind them. Enthusiasts call them thunder boats. But thunder isn't enough for the man setting out to break the surface vessel speed barrier within the next year. He needs lightning.

The elusive barrier is Mach .5—one half the speed of sound—or 385 mph at sea level. (The speed of sound is roughly 700 mph. It changes with variations in air pressure and temperature.) The last man to try it was Lee Taylor, who took the sleek *U.S. Discovery II* to Lake Tahoe in November 1980. His 40-foot, 2,500-pound craft was powered by the brute force of 8,000 pounds of thrust in a 16,000-hp Woodruff rocket engine.

Writer: Dennis Eskow, Science Editor
Reporters: William Hoffer, Newport News, Va.; Lee Green, Bonneville, Utah; Ted Francis, Los Angeles; Allan Efrus, New York



PHOTO BY D.W. WOODRUFF

Lee Mize's *Screamin' Eagle* (top) will try breaking the Mach .5 barrier on water. The British Thrust 2 car (above) is being readied for an attempt at Mach 1 on land.

Fifty yards into the run an inspection plate blew off the side of the vessel, leaving a gaping hole. Unaware of the damage, Taylor blasted toward the measured straightaway. As he brought the craft over 280 mph, the hole began sucking in air like a jet engine. Suddenly, the entire boat exploded. Taylor was knocked unconscious and his motionless body, strapped into the bulky cockpit, sank into Lake Tahoe. It took

divers a full week to find his remains.

The tragedy left Taylor's friend Lee Mize as the only serious American challenger to the Mach .5 barrier.

"Taylor's boat had serious engineering problems," claims Mize, holder of four world records in various drag boat classes. "I saw problems with the way water was hitting his sponsons. I thought it would hammer his boat, breaking it apart. He didn't think I had

BREAKING SPEED BARRIERS

New rudders and body design will be used by *Screamin' Eagle* (left) to go for Mach .5 on water. Under water, the Soviet *Alfa*-class sub reportedly breaks the 42-knot barrier. *Thrust 2* uses big engine and high fins. It's going for Mach 1. Don Vesco's motorcycle has gone 318 mph. He's shooting for 425 mph. A futuristic SCRAMJET will eventually go for Mach 7. Far in the background are an aerodynamic Human-Powered Vehicle and a man.

MAN MILE:

3 MIN. 47.14 SEC.

HUMAN-POWERED
VEHICLE

65 MPH

SURFACE BOAT
MACH .5

a safe boat and I didn't think he did."

Five years after the tragedy, Mize is now certain his boat is ready to break the barrier safely. When he takes out his rocket-propelled *Screamin' Eagle* late this year or early next year, he'll rely on his own patented fish-scale design at the bottom of his sponsons that allows the boat to leave the water in stages as speed is increased. At 100 mph, only tiny fins beneath the sponsons will touch the water.

"At high speed, water is like glue," Mize explains. "If water touches the boat, it grabs it like brakes grabbing an icy road." At a speed of 200 mph, contact with 1 square inch of water will rob a hydro of 50 hp.

For safety and stability, the *Screamin' Eagle* has both an air rudder and a water rudder. Mize had warned Taylor that his oversized water rudder would create control problems once the craft left the water, which it must do as it approaches the speed barrier. The 20-foot *Screamin' Eagle* is designed to stay in control as its 95 percent hydrogen-peroxide fueled rocket booster revs up to 20,000 hp. The boat, Mize says, is pure lightning.

"If we were to set this boat on its tail, we have enough power to shoot it, with me in it, 60 miles straight up," he claims. In early test runs, Mize took the boat up to 180 mph using just 10 percent of its power. Taylor was asked just before the fatal run what his next goal would be after breaking Mach .5. "Break the sound barrier," he replied. Mize will settle for half that on his run.

The Mach 1 car

Since 1963, Mach 1 has been the speed barrier to a dedicated group of enthusiasts who haunt the salt flats of Bonneville, Utah. That was the year Craig Breedlove's three-wheeled *Spirit of America* brought jet power to Bonneville. Running his jet car over 400 mph for the land speed record, Breedlove brought a new dimension to this unusual class of vehicle.

By 1970, Gary Gebelich, driving the jet-powered *Blue Flame*, hit 622.407 mph for the "flying" mile. In 1973, Britain's team headed by Richard Noble set out to design the ultimate Land Speed Record Car. The machine was dubbed *Thrust 2* after a prototype was wrecked and sold for scrap for \$500. The 27-foot,

8,500-pound *Thrust 2* is powered by a modified Rolls-Royce Avon 302 jet engine with 17,000 pounds of thrust.

The Britons went to Bonneville in 1981 and 1983, but each time they arrived, flooding had made the track impassable. In '83, they attempted to break the Land Speed Record at Nevada's Black Rock desert. Noble ran *Thrust 2* beyond 633 mph, breaking the record by 33 mph. But it was far short of Mach 1, about 730 mph.

Noble and his team are working on the aerodynamics of the *Thrust 2* body this year. They are expected to raise the already 4-foot-high fins and to shave a fraction from the belly of the car. A larger engine is also on the drawing board. No announcement has been made as to when the Britons will try it, but the entire Land Speed Record community is expecting the Mach 1 barrier to fall by next year.

One Land Speed Record car already has gone Mach 1, but the speed wasn't documented according to the official rules. The *Budweiser Rocket* hit an unofficial 739.66 mph—Mach 1.01—in tri-



WINGED AIRCRAFT

MACH 7



MOTORCYCLE

425 MPH



THRUST 2

LAND SPEED RECORD

MACH 7



SUBMARINE

42 KNOTS

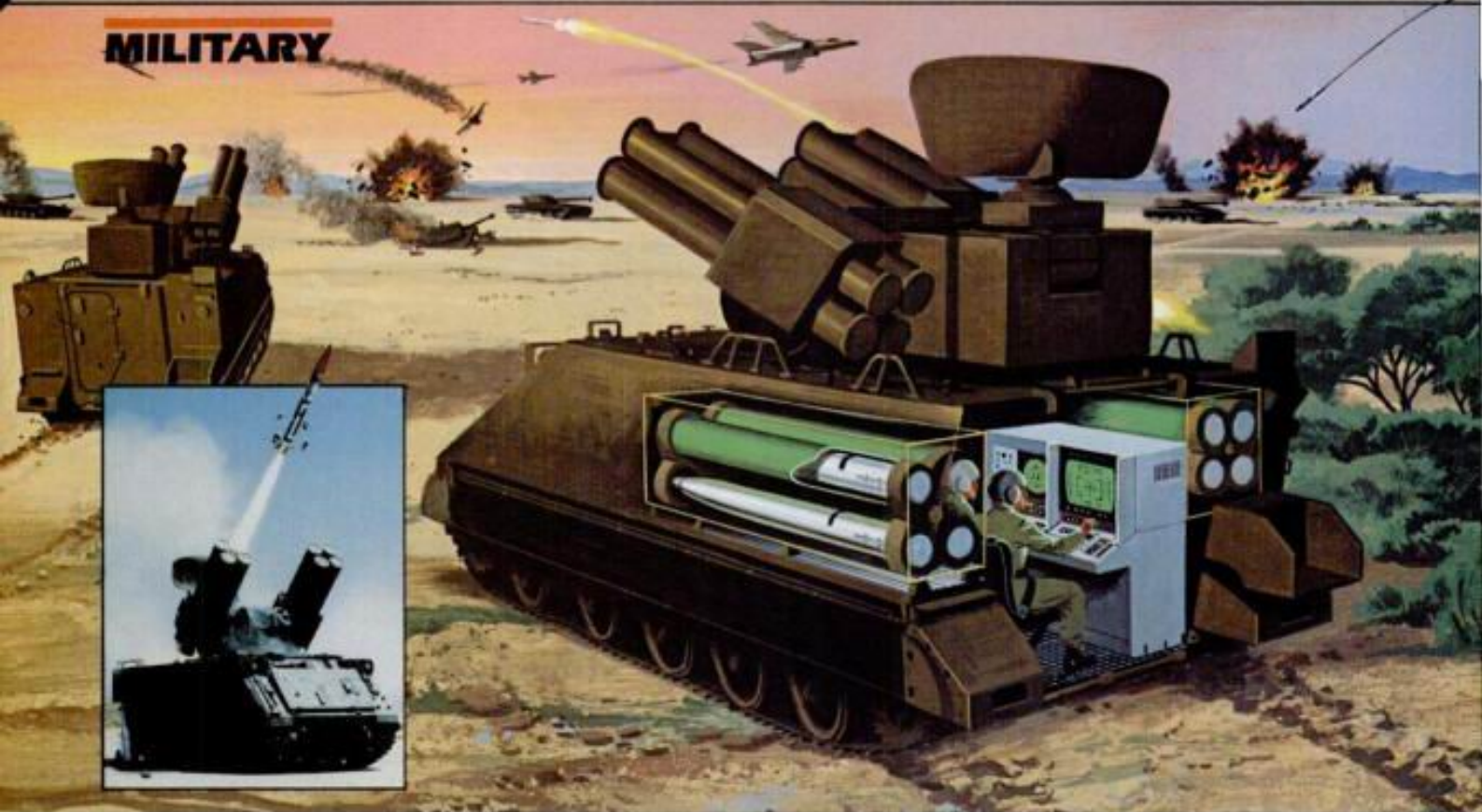
als at Edwards Air Force Base in 1979. The rules specify that any new record must be the average of any two runs over a measured mile or kilometer conducted within 30 minutes of each other with all timing done by official observers using approved calibrated instruments. The *Budweiser Rocket* was clocked by an unsanctioned Air Force officer without the requisite equipment.

Will Mach 1 ever be reached on land? "I think it's quite possible," says Noble. "After all, we know the airspeed along

[\[Please turn to page 114\]](#)

PM DRAWING BY ED VALIGURSKY

MILITARY



Hot new missiles: No place to hide

It's getting harder and harder for an enemy to hide. The two new mechanized missile launchers shown here are designed to make it virtually impossible for a hostile force to avoid detection and ultimate destruction. At left above is the ADATS (for Air Defense Anti-Tank System), the first dual-purpose missile launcher capable of defending against both ground and air attack. Enemy targets are detected and tracked by a combination of day/night sensors, including radar, TV and infrared, making it possible for gunners inside the vehicle to see the targets on video screens even in darkness and bad weather.

Once a missile is launched, it is automatically guided to the target by riding a coded laser beam. It has a ground range of five miles and is effective to an altitude of 16,000 feet against airborne threats. The eight-missile ADATS launcher, in addition to being vehicle mounted for mobility, can also be used in fixed emplacements such as for guarding airfields and coastal approaches. It was jointly developed by Oerlikon-Buhrle in Switzerland and Martin Marietta Aerospace here.

The vertical-firing antitank weapon shown on the facing page can hide safely behind a hill or other cover and lob its missiles at



Fast help for fast ships

The Navy's high-speed hydrofoil patrol boats need to know exactly what's ahead at all times, especially when they're in tricky waters, since a suddenly looming threat could come too fast to avoid.

Now, a Sperry-developed system called HYCATS (Hydrofoil Collision Avoidance and Tracking System) makes navigating faster and easier. A conventional radar plot is superimposed on a moving map display of a harbor or coastline. Thus, a navigator can quickly see not only radar blips, but his own ship's position in relation to land contours, channels, navigating hazards and other ships.

Dual props boost boat speed

When are two propellers better than one? When they're turning in opposite directions. That's the secret of a new twin-prop sterndrive under development by Volvo, maker of the popular Swedish Volvo car. A single prop turning in one direction produces a reactive force, called prop torque, that tends to twist the boat in the opposite direction, wasting power. A second,

counterrotating prop cancels out prop torque and converts wasted energy into added thrust. The dual props, driven by reversing gears on concentric shafts, also allow the engine to run at a lower, more efficient speed due to the greater blade area.

Called Duoprop, the system has produced some impressive test results: a 10 to 20 percent increase in cruise speed, a 30 percent boost in burst acceleration and fuel savings of up to 15 percent.





PM ILLUSTRATION BY DEAN ELLIS

unsuspecting attackers miles away. The secret: As a missile is launched, it pays out a fine optical fiber—like fishing line spiraling off a spinning reel. A TV camera in the missile's nose scans the battlefield for hidden enemy positions and transmits visual images back to video monitor screens over this fiber-optic link. When a tank or other armored vehicle is spotted, the missile is automatically guided to the target by computerized instructions fed to it over the same umbilical link. Called FOG-M (for Fiber Optic Guided—Missile), the system is a joint Hughes Aircraft/U.S. Army development.

NEW NAVY
T-45A TRAINERNEW AIR FORCE
T-46A TRAINER

New planes for future fliers

Fledgling Navy and Air Force pilots will soon get their hands on hot, new training planes designed to more closely simulate the fighter jets they will eventually fly. The Navy's new T-45A is a derivative of Britain's highly successful Hawk trainer now being modified for U.S. carrier operation by McDonnell Douglas. The versatile, 600-plus-mph tandem two-seater will replace two current Navy trainers, the intermediate T-2C Buckeye and the advanced TA-4 Skyhawk. It will cut training time by 25 percent and training cost by almost 50 percent.

The new Air Force/Fairchild T-46A is a 450-mph, side-by-side primary trainer designed to replace the aging T-37 Tweet, in service since the mid-'50s. It will be faster and more maneuverable than the T-37 while burning only one-third as much fuel. It will also have removable wings. Why? So it can be trucked back to base if an errant trainee comes down in a cornfield.



Self-propelled rescue rig

Rescuing an injured or unconscious victim at sea is difficult, especially in rough waters, because he can't help himself. Now you just send out this self-propelled basket, scoop him up in it and haul him to safety without having to risk the lives of rescuers.

The remote-controlled rig, which can be launched from a ship or helicopter, is supported on inflatable pontoons and powered by two variable-speed, reversible electric thrusters that permit it to be steered by rescuers through the water to the victim's location. Called Jet-Net, the rig is made by SEI Industries, Vancouver, B.C.

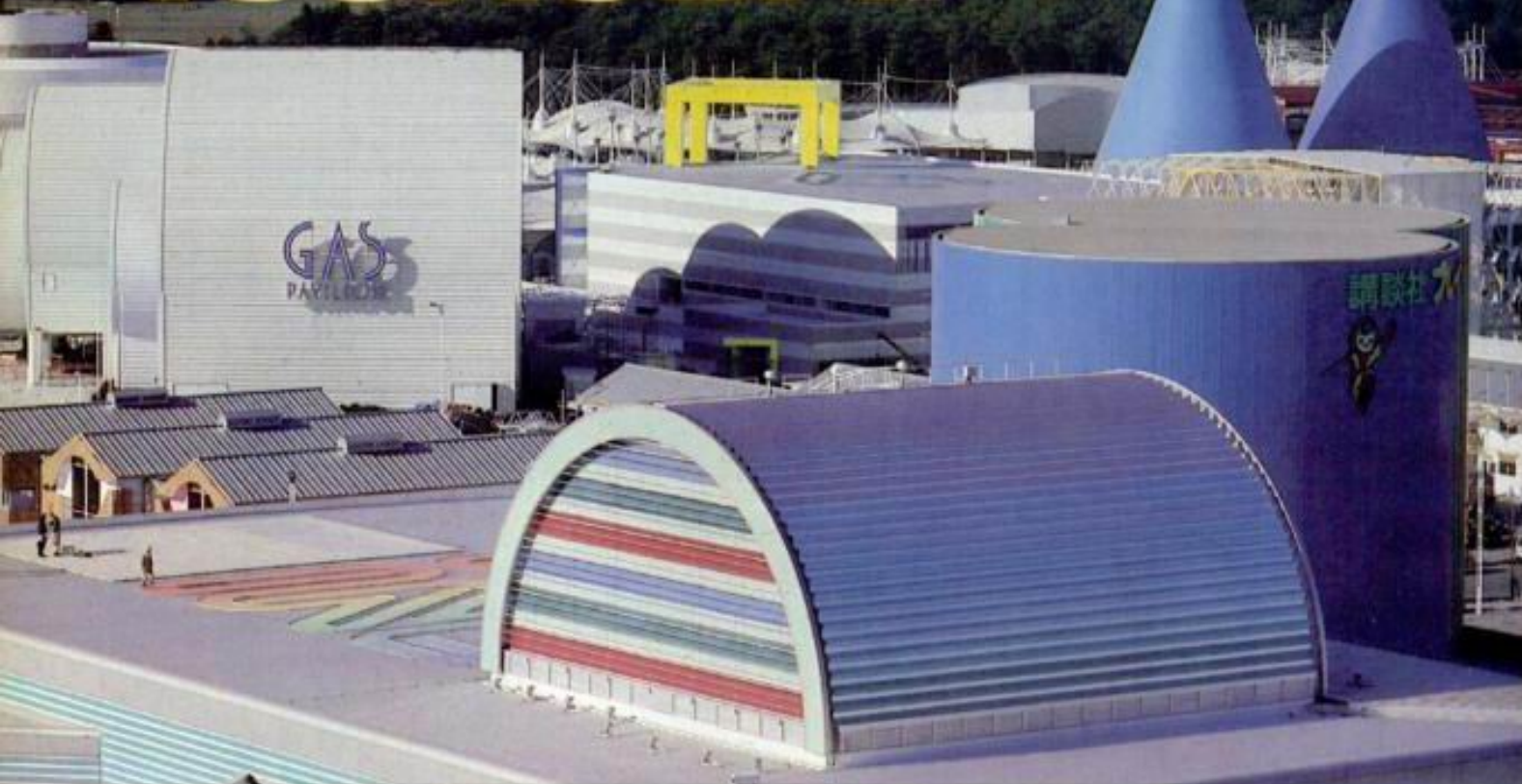


Record-breaking speedboat

The trouble with conventional hydroplanes, says speedboat designer Tom Austin, is that they become virtually airborne to reduce water drag, yet aren't designed to fly. Resulting instability makes them hard to control and limits their speed.

Austin's answer is a twin-hulled, center-wing craft that flies like an airplane while scarcely touching the water. Aileron-like vanes at the sides provide roll control, while differential rudders in the tail control both pitch and yaw. Under development at Austin Aeromarine, Las Vegas, Nev., the Ram-2 currently is powered by two 135-hp outboard motors. With bigger engines, it may be able to exceed 250 mph—enough to set a new world speed record for prop-driven racers. **Tu**

EXPO '85 AT TSUKUBA:



JAPAN STRUTS ITS STUFF

With oriental subtlety, Japan is unveiling future technology at its \$250 million Expo.

BY DENNIS ESKOW, Science Editor; Photos by Brian Wolff

My hand trembled as I reached for the dashboard shifter of the train that literally rides on air. I pushed it to the first stage and the 12-ton car rose slightly off the track, perhaps less than an inch. Another push on the shifter and we floated off—me, the *untenshu* (motorman) and 40 passengers who didn't know I was the driver. Silently, smoothly, we glided away, following the track to the terminal, a little over 1,000 feet away.

"Be ready," the *untenshu* grunted from his seat behind me. "Okay, now push again...we go down." I pulled back on the lever and we glided smoothly into the terminal, setting down as lightly as rice paper on the track. Here I was, almost at the end of my visit to Expo '85, Japan's version of a World's Fair, and I had become the first American to operate the Japan Air Lines maglev train.

Maglev, like many of the other 45 main exhibits at Expo '85, is Japan's subtle statement to the world. The fair, located about 25 miles from downtown Tokyo, is a quarter-billion-dollar wonder that will be transformed into a new Science City in the town of Tsukuba (pronounced *schooba*). "When the fair



■ Tsukuba is 25 miles north of Tokyo. Current bullet train, commuter train and expressway routes between Tokyo, Expo '85 and the airport are shown at left. A maglev train (right) from the airport to Tokyo will cut to 20 minutes a trip that currently takes autos anywhere from 1½ to 3 hours.



■ Main Exhibit area includes futuristic buildings of modular construction. All will be totally dismantled during a brief 30-day period following the closing of Expo '85 early next fall.



■ Japan Air Lines' HSST maglev train runs on a cushion of air just above the track. The electrified track has a magnetic field oppositely charged to that of the magnet attached to the train. An amplifier built into the car's undercarriage creates magnetic pulses to move car.

PM ART DALE GUSTAFSON

■ Sony's spectacular JumboTRON color TV screen is 65 ft. high and 110 ft. wide. It's made up of 6,300 units, each containing 24 fiber-optic light-emitting cells (inset).



is over, all the buildings you see will come down in one month and you will see research buildings in their place," said Katsuichi Ikawa, commissioner general of Expo '85. "We already are talking with some 20 high-tech companies about setting up their research sites here."

Unlike the last two World's Fairs held in America—in Knoxville, Tenn., and New Orleans—Tsukuba opened in March with few expectations for its financial success and little fanfare about its technologies. The organizers hope to accomplish three things with Expo:

First, they want to show the world where Japanese technology is heading. Second, they intend to transform Tsukuba into a major research center. And last, they hope to draw about 20 million Japanese visitors and some 2 million foreigners to the fair before it closes this fall.

Judging from the array of exhibits, the first point is well established. Maglev, for instance, is no longer a drawing-board dream of the future. With its High Speed Systems of Transport (HSST) car on display, Japan Air Lines is giving Expo visitors a preview of things to come in the 1990s.

"By then, we hope to have an HSST running from Narita Airport into central Tokyo," said Morris Simoncelli, JAL's American spokesman. Currently, the bus or auto ride from Narita to Tokyo runs anywhere from 90 minutes to three hours, depending on traffic conditions. When maglev trains begin operations, it will take under 20 minutes.

The advantage of maglev trains is the fact that they levitate and ride above rather than on the track (see *Coming: The Fastest Train In The West*, page 90, Nov. '83). This allows them to move at demonstrated speeds well over 150 mph while drawing no more power than an ordinary subway train.

The model being shown at Expo '85 is an aluminum shell sitting on alumi-

num alloy spars. The car travels above an electrified track shaped like an upside-down U. Extending across the bottom of the car is an amplifier that carries electric pulses to a U-shaped superconducting magnet. The train's linear induction motor provides power for the pulses.

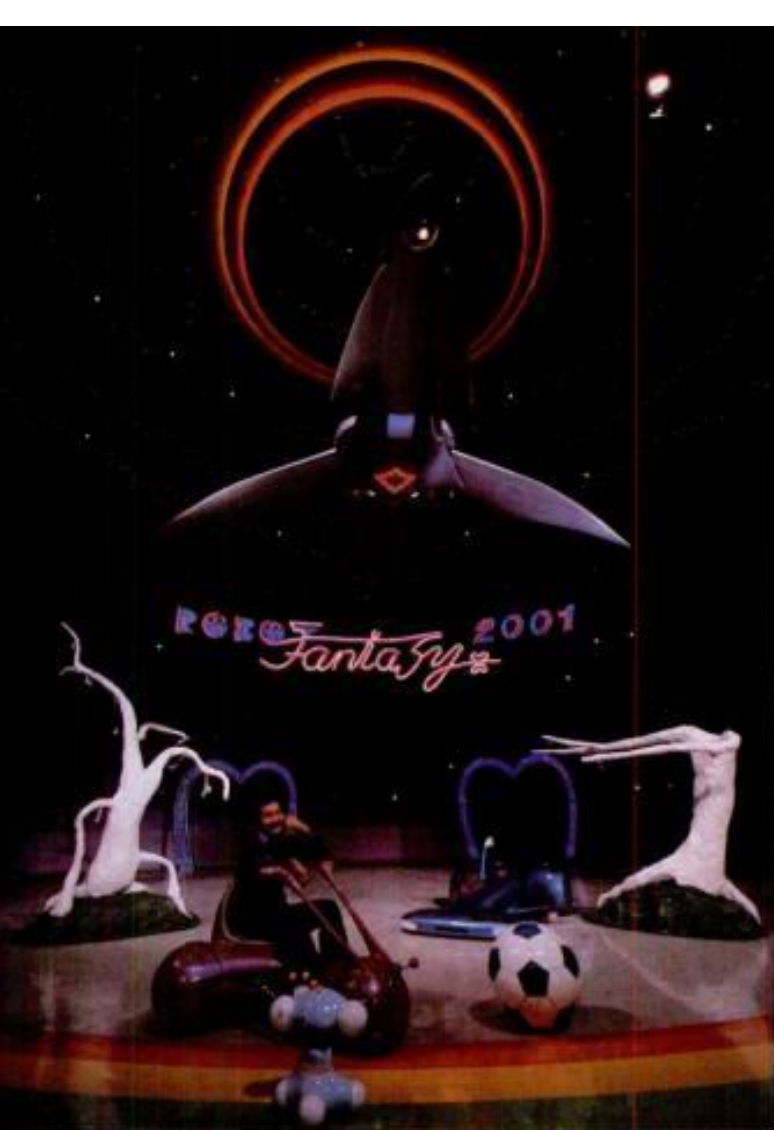
The train's magnet is oppositely charged from the rail so that the maglev car rides above the rail. As the amplifier is pulsed on and off, the changes in magnetism push the train on its course.

The technology has been in development since the 1970s and now appears ready for everyday use. The last obstacles in the way of an airport-to-city system include smooth track switching and easy braking at high speeds. The Japanese believe these will be solved within the next five years.

The JAL maglev takes you from a spot near the Expo entrance to a back gate area. From there, you can walk the 250-acre park easily in one day. From the outside view, Expo is an update of Disney's Epcot Center in Orlando, Fla. You have to get behind the scenes to get the full impact of the hottest technologies.



■ Learning with laughter: In the Expo's Children's Park, youngsters can stroll across a relief map of the world, or they can amuse themselves by playing with scientific gadgets.



Sony dazzles visitors with its 65-foot-tall, 110-foot-wide JumboTRON color TV screen. It's stunningly sharp and the colors are true to life. You might think it's nothing but an overgrown TV set. But in the panel behind the big screen sits the future of video technology.

Instead of building a mammoth vacuum tube—which would have been impossible—or using a system of light-emitting diodes, which would have produced a faint picture, Sony created a new technology for JumboTRON. The screen is composed of 6,300 units, each containing 24 three-color light-emitting cells. Each is connected by fiberoptic cable to a computer station beneath the screen.

By plugging thousands of cells into a central computer, yet giving each one an individual output line, the JumboTRON screen can produce hundreds of shades of each color for a remarkably realistic picture. The outdoor display screens you see in sports stadiums today have a resolution of about 70,000 pixels. But JumboTRON has a resolution of over 400,000 pixels, about the same as the TV in your home. The new technology may be miniaturized in the next decade for use with large-screen household television sets.

The Japanese also are showing off their latest robots and computer technologies. In the Fanuc exhibition, an 8-foot-tall robot that runs on a 256K computer uses a set of 16 servomotors to do all sorts of chores. It can lift over 200 pounds or work so delicately that it can build an 11-inch replica of itself in a



Workers put final touches on musical water fountain outside main pavilion. Inside the Fuyo Robot Theater, producer Shuichi Kanno (left) sits atop one of his buggies to be driven by robots.



Fanuc Man is an 8-ft.-tall robot whose steel and servo-motor make-up provides great strength and dexterity. Fanuc man lifts over 200 pounds and builds 11-in.-high replicas of itself.

few minutes. This is the shadow of a factory to come, where the robot assembles, packs and loads merchandise.

In the computer field, Expo is featuring an "intelligent" system that can translate Japanese and English conversations. The software is designed to translate the most difficult idiomatic expressions by first searching for the literal meaning of the words in the sentence, then testing for the logic of the word order, then matching illogically ordered words with a lexicon of clichés and idioms.

"The Japanese word for delicious is *umai* and the word for hand is *teh*," explained Hiroaki Eguchi, a researcher for Fujitsu. "If the computer reads a sentence that calls something an *umai teh*, it recognizes that delicious hand makes no sense. These words are then matched against a catalog of idioms and the computer learns that *umai teh* means a good idea. It all takes 20 to 30 seconds."

If the high technology aspects of the fair are hidden behind the scenes, so are many of the engineering technologies. The buildings are constructed of modular lightweight aluminized steel panels and prestressed concrete blocks on jacks that allow for easy moving.

It doesn't dazzle the eye, but it staggers the imagination to realize that all this is coming down to make way for the new Tsukuba Science City.

Where Expo now stands, more than a dozen electronics and engineering firms are expected to erect research and development centers early next year. The excitement is building up at Tsukuba.

More than 4 million Japanese travelled abroad last year, and the Expo backers are hoping that much of that trade will be kept home this year. And, if you ever thought about visiting Japan, Expo '85 might be the best excuse you'll ever have. That's what the Japanese are hoping.

PM



The single-car maglev (magnetic levitation) train carries passengers around Expo.

PM TECHNOLOGY UPDATE 8/85

ENGINEERING

Hull aids Gulf exploration

The waters in the Gulf of Mexico are often rough and choppy. *Twin Drill*, a geo-technical survey, salvage and maintenance vessel, is especially suited for the Gulf's churning seas. Using SWATH (Small Waterplane Area Twin Hull), a catamaran-type hull design, *Twin Drill* rides steady in white-capped water. *Twin Drill*'s unique configuration allows it to moor in water as deep as 600 feet. The ship is held at station either through a four-point, winch-driven mooring system or by manual T-stick control of thrusters. The ship's deck has a 23-foot, circular access port known as a moon-pool. Submersible vehicles can be recovered or delivered through the opening. *Twin Drill* is equipped with a full-scale laboratory for on-the-spot analysis of core samples and information on soil conditions. Although soil analysis and ocean-floor probes are the craft's main activities, its other functions are sub-sea work, diving, platform and cable maintenance, and inspection. *Twin Drill* this summer is conducting a search for new oil fields in the Gulf of Mexico.



Twin Drill's SWATH hull gets final touches in Rotterdam.

Fish farming for profit

Why is multimillionaire industrialist Robert Abplanalp raising tropical fish? Because there's money in it. Abplanalp recently opened the world's largest saltwater

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fish hatchery, capable of producing 1.5 million fish a year. The 23,000-square-foot fish farm, located in the Bahamas, uses the latest mariculture technology to net an estimated \$2.5 million a year. Overhead tubes (top) supply clean sea water to 200 brood stock tanks. Fish mature in one of 250 growing tanks (bottom). This may improve reef ecology, since tropical fish traditionally are caught after being stunned by toxins or explosives.



AEROSPACE

Space ferries for the 1990s

The initial success of America's Shuttle program has spawned similar efforts in France and the USSR. While both projects are only in planning or test phases, both countries already envision using a returnable vehicle within the next 10 years.

A Soviet prototype is reported under construction. When complete, the vehicle is expected to resemble the model at right (foreground). The actual 1-ton Kosmos 1614 space plane is shown (black and white reconnaissance photo below) during a recovery mission in the Black Sea. According to spokesman Roald Sagdeyev, head of the Moscow Space Institute, the Kosmos flights will determine profitability of a reusable system. At present, Sagdeyev says, reusable shuttles are not profitable. But the Soviets are watching the American Shuttle program in hopes of building on what NASA is learning from experience.

The proposed French vehicle, a delta-winged Hermes, is a 50- to 60-foot returnable craft (a mock-up is shown at right, above the Russian model). The French expect to use Hermes for high-orbit transfer



PM ILLUSTRATION BY BRIAN SULLIVAN



Recon photo shows Soviet ship recovering space plane.

of crews and supplies to manned space stations and in-orbit servicing of platforms and satellites. The French are considering two designs, both similar to NASA's orbiter. With the success of both programs, travel and work in orbital space will amount to nothing more than a ferry ride.

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3M, GM share

General Motors will use 3M Corp.'s Chemical Reaction Chamber to test the effects of microgravity on nylon production during a Shuttle flight in November. GM scientists say the experiment will show the effect of crystal structure on the wear-resistance and elasticity of nylon, which is important to automotive components. Also, 3M will use the electrically heated chamber to continue crystal growth experiments begun aboard a



Shuttle flight last fall. Above, 3M researchers place 6-experiment chamber in a self-contained canister.



PM ILLUSTRATION BY ED VALIGURSKY

ENGINEERING

Longest tunnel

In 1988, travelers between Japan's northernmost island of Hokkaido and the main island of Honshu will span the 33½-mile gulf of open ocean using the world's longest underwater tube, the Seikan tunnel. A

completed portion of the tunnel is shown in the photo at right. Vehicles and passengers will board bullet trains and speed to their destinations, avoiding the storm-plagued ferry service above. The trip will take one-third the time. Horizontal tubes will connect the main tunnel with a service tunnel (illustration above) for emergency repairs or evacuation. Construction



began on the tunnel 21 years ago, boring through fracture-prone rock called tuff.

Sound magic

Sonic waves can move or lift things, and Cal Tech jet propulsion researcher Taylor Wang has devised a sound chamber which amplifies and directs sound to lift light objects. The future is unlimited, says Wang. Acoustic levitation in space can move objects and mix chemicals. On earth, it may generate heat.

SPECIAL REPORT: ADVANCES IN LASERS

Laser aids in fusion

University of Rochester scientists' attempts to create a fusion reaction using an infrared laser beam proved fruitless until frequency converters (below, right) were employed to boost the energy of the 24-beam laser array (bottom) to ultraviolet wavelengths. The full energy of the beams was focused on a target pellet (photo right) and a successful fusion reaction was initiated.



Forecast: light trickle

Farmers can save miles of pipes and conserve water using the computerized, solar-driven Traveling Trickle Irrigation System (TTIS). The system uses a laser guidance mechanism to guide the TTIS towers between the crop rows. In addition, solar cells provide power for moving the TTIS over the fields. Infrared thermometers, traveling atop the TTIS towers, are used to calculate the crop's exact water needs and are proving valuable in the Southwest.



MILITARY

Missile shuffle

How do you protect your missiles from enemy attack? Instead of storing them in fixed silos, you keep moving them around in mobile launchers so the enemy never knows

exactly where they are. At left, above, is a joint Boeing/Goodyear concept for a low-slung, tractor-drawn launcher capable of operating over rough terrain.

To fire the missile, the launcher is raised hydraulically to a vertical position. Not to be outdone, the Russians are developing a similar wheeled launcher (right).



Luftwaffe orders better radar

West Germany is improving the combat efficiency of its F-4F Phantoms with Hughes' APG-65 radar system. APG-65, in the nose of the F-4F

above, is an all-weather sensor designed to incorporate air-to-air and air-to-surface features. It will provide look-down/shoot-down capability

as well as the ability to track 10 targets at once, displaying eight. The upgrade will keep the F-4F in service to the end of the century.



The Phantom strikes again

The 25-year-old McDonnell Douglas F-4 Phantom fighter has proved so rugged and reliable that it's now about to get a facelift that could extend its operational life well into the next century.

To be called the Super Phantom, it will, in the next two years, get more powerful engines and advanced avionics, as shown above.



Red hot chopper

The Russians are about to field a potent new attack helicopter, according to U.S. Defense Department intelligence reports. Known as the Mi-28 Havoc, it has an unusual 5-bladed rotor and a laser guidance system for delivering antitank missiles with pin-

point accuracy. In size, speed and striking power, it is believed to be comparable to our own Hughes AH-64A Apache helicopter, making it a deadly adversary.

Like the Apache, the Havoc is powered by twin turbines and has a 2-man, tandem cockpit with stepped seats so the gunner in back can see over the pilot.



Blimp boat

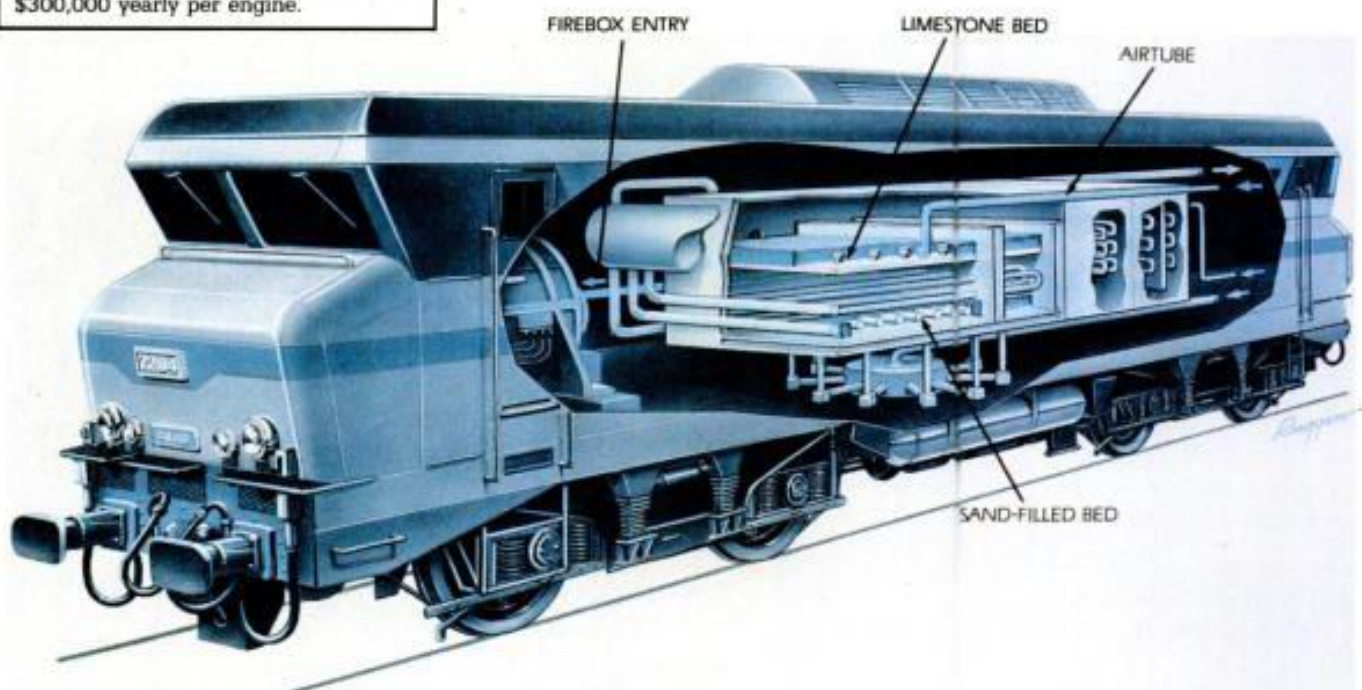
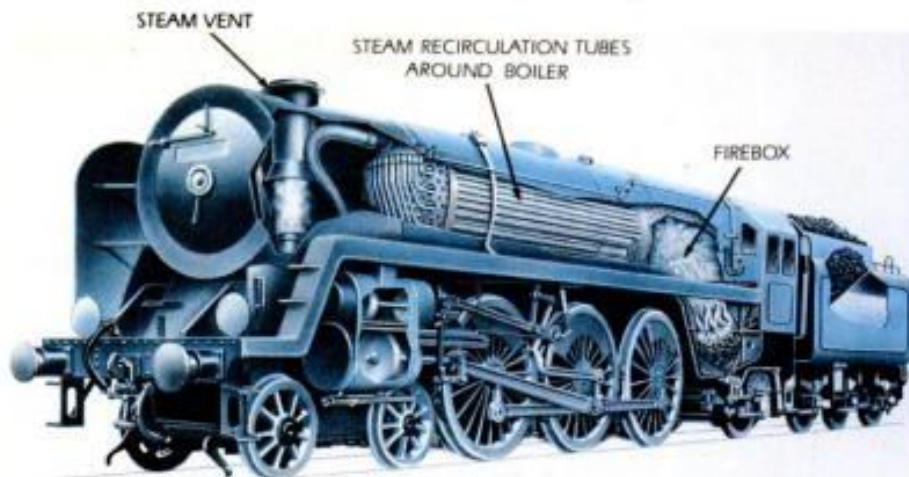
When this British coastal patrol blimp wants to search a vessel or rescue a shipwreck victim, it doesn't have to call for help. Hidden under the gondola is a small, fast speedboat that can be lowered into the water quickly. Developed by Airship Industries of London, the system is under study by the U.S. Navy.



How new engines work

Artist's conception of two future steam engines shows newest technologies. The American Coal Enterprises engine (top) would put out little steam, since it would be recirculated through pipes around the boiler. A steam vent would bleed off small amounts. Prepackaged coal would be fed into the firebox automatically from a coal tender. The ACE engine's operation costs would be half that of diesel.

The National Steam Propulsion engine would process fuel through a pair of air-blown "fluidized beds," a limestone bed on top and a sand-filled bed on bottom. The system makes coal-burning a clean process. The waste product is gypsum and limestone, which can be used to make construction materials. The system, known as the Wormser Grate, would make it possible to burn the cheapest fuels to save more than \$300,000 yearly per engine.



The Chattanooga Choo Choo And Smoke Gets In Your Eyes

Number 611 chugs along at the head of an elongated train of 21 coaches, pulling nearly 1000 nostalgia buffs along 150 miles of track between Atlanta and Chattanooga. This is one of 90 steam locomotive excursions that Norfolk Southern Railway will run this year between various U.S. cities. This particular trip is cosponsored by the Atlanta Chapter of the National Railroad Historical Society. Tickets are hard to come by.

Families dig into their picnic coolers. Grandparents shepherd wide-eyed children through the crowded aisles. Scores of sightseers cluster on the two old-fashioned open coaches where, through eyes protected by goggles, they can get a better view of Number 611 at the head of the procession. Everyone along the route pauses to stare at the relic reminiscent of the glory years of American railroading. No one can resist a wave.

"I cut my teeth on steam locomotives," Bill Purdie declares from his seat in the VIP club car. "Diesels, well, yeah, they save the railroads. But they're not as personable as steam locomotives." Purdie is retired now from his career as a master mechanic for Norfolk Southern, but he well remembers the day in 1981 when Number 611 was towed into his roundhouse in Birmingham and he was given the job of restoring her.

"There were 14 of her class built, but all the others were

scrapped," he says. "If they'd have just stayed with the steam locomotive a little longer, they'd have improved it. And the diesel would've had a tough time taking over."

Three hours into her journey to Chattanooga, Number 611 stops on a deserted straightaway near Phelps, Georgia, for a photo run-by. Passengers disembark and gather alongside the track. Number 611 slowly backs up, preparing to roar past the onlookers at full speed.

Puffs of black smoke suddenly shoot skyward from the stack of Number 611 as, in the distance, the streamlined behemoth begins her run. Her ball-bearing construction—an innovation when she was built in 1950—allows her to gain speed much more quickly than her primitive ancestors.

You can feel the power—perhaps even more than you can hear the accelerating, approaching roar. Down the track she comes, her sharp chugging sound echoing off the distant Appalachians, her steam whistle shrieking the banshee call of a past age of glory.

Suddenly, she is *there* encompassing your every sense, a more powerful presence than any diesel-electric locomotive ever built. Her sheer size is staggering. She explodes past, spewing a thick black cloud that quickly descends upon her band of admirers.

Cinders attack your clothing and lodge in your hair.

Smoke gets in your eyes.—W.H.



150-mile run from Huntington to Hinton, West Virginia, pulling 3500 tons of coal along the tracks of the Chessie System. Children lined the route to see the glorious sight of the old-fashioned train as it bellowed smoke out over the countryside. Rowland delighted them by tooting the steam whistle frequently.

Number 614 was one of the last steam engines built in America. The Lima Locomotive Works popularly referred to it as a "Super Power" locomotive. It had an overly large firebox and improved features to utilize as much steam as possible for power. When the Chesapeake & Ohio Railway took delivery of Number 614 in the summer of 1948, it immediately put it into service on its passenger line running between Hinton and Charlottesville, Virginia, the most rugged section of the C&O main

line, rising up and over two separate mountain ranges. Due to its excellent performance, the C&O was able to extend Number 614's run all the way to Newport News, Virginia, a total distance of 347 miles. Weighing in at 434.2 tons, its drive wheels standing 74 inches tall, Number 614 was nonetheless doomed to a short life. New technology reared its head.

In 1952, after only four years of service, Number 614 was bumped off the elite passenger line by the incoming diesel-electrics. It hauled coal for another four years before being shunted off to early retirement.

Most who came to view it at the B&O Railroad Museum in Baltimore saw it as a relic of the past. Rowland, however, had a special vision. When steam locomotives were discarded three decades

The Strasburg Railroad (above) carries a full line of passengers each weekend. The railroad maintains its own shop (below).



Chattanooga 611:
110 mph on 5000 hp.



ago, their death knell sounded so quickly that no one thought to apply new technology to them.

But Rowland had never forgotten the big, beautiful beasts. In 1966 he founded the High Iron Co., which restored steam locomotives and ran them on nostalgic excursions throughout the Northeast. The Freedom Train was Rowland's contribution to the American bicentennial celebration. The half-mile long, red-white-and-blue train was pulled by a steam locomotive through 48 states.

But nostalgia was not enough for Rowland. In 1980, he founded American Coal Enterprises (ACE) and announced his ACE 3000 program to combine 150 years of locomotive development experience with major engineering advances that have occurred in the last 40 years.

Thus it was that Number 614 lum-
(Please turn to page 114)

RESCUE

Lifeboat capsule

West Germany's Survival Satellite (top) is touted as the lifeboat that will reduce the 2000 lives lost annually in marine accidents. The satellite is launched from a foundering ship via an inclined slipway (bottom right). The watertight, bullet-shaped unit holds 45 people. After it's launched, it dives to 65 feet and can remain submerged until its 35-hp diesel engine propels it out of danger. It can be loaded and launched in two minutes and its lightweight steel hull is fireproof and heatproof (bottom left). At least two of the survival satellites currently are safeguarding passengers and crew on West German refrigerator ships.



ENERGY

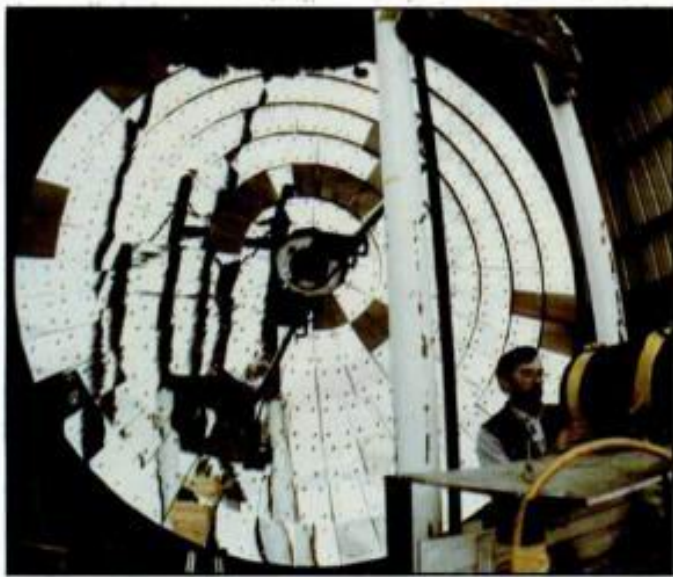
Furnace aids research

Sandia Laboratory scientists are using their solar furnace (left) to test effects of high temperature on materials used in solar facilities and nuclear powerplants. It consists of a sun-tracking mirror array that reflects sunlight onto a parabolic dish solar concentrator which focuses sunlight onto a platform holding test objects. Researchers plan to use the furnace to produce high-purity silicon.



Sun repeater

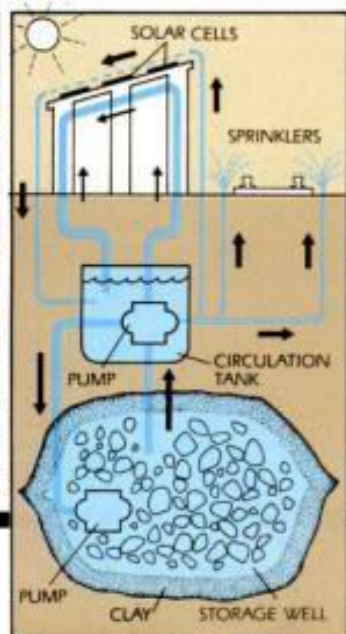
Isolated repeater stations require power to boost radio signals and occasionally are so remote that fuel or power lines are difficult to provide. Arizona's public safety agency uses a photovoltaic array to power their station 60 miles from Phoenix.

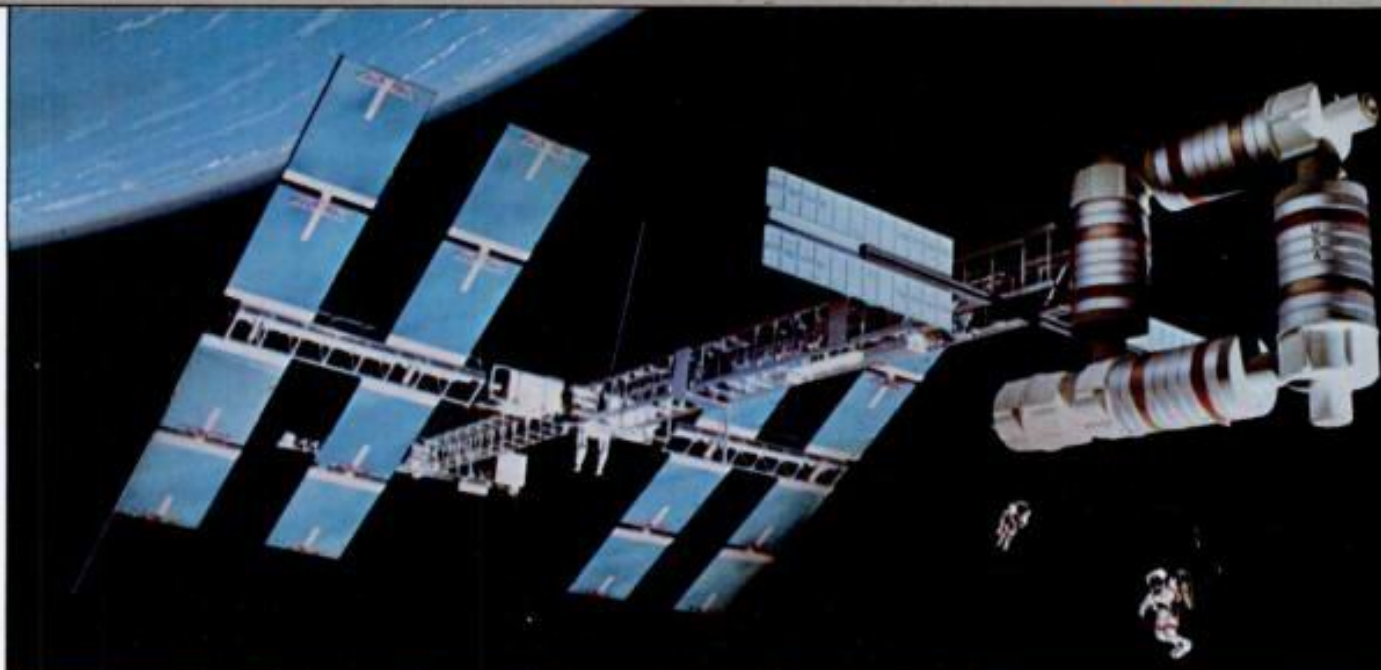


Solar heat clears snow

A Japanese National Railways research group is using solar energy, stored as warm water during summer months, to melt snow along tracks and rail stations on the bullet train lines (far left). During initial tests, solar energy was collected on a station rooftop (illustration at left) and stored as 10,000 tons of heated water underground at the station compound at 90°F. During January, pumps were used to

propel the heated water to sprinklers on the station roof and along nearby tracks. The temperature at pumping was approximately 64° to 68°F. The melted snow (as well as rain) was collected, pumped to a heating tank, then stored in a well surrounded by clay insulation. The test showed that 34,000 gigacalories of solar energy—the equivalent of 22,500 barrels of oil—could be stored between April and September. The system may be modified to store cold air in winter for air conditioning.





AEROSPACE

NASA orders space designs

NASA has chosen the Martin-Marietta Aerospace and Boeing Aerospace Co. to design modules for the proposed space station (drawing top) scheduled for assembly in the 1990s. Boeing is developing a design of a pressurized common module (above right). The Boeing design



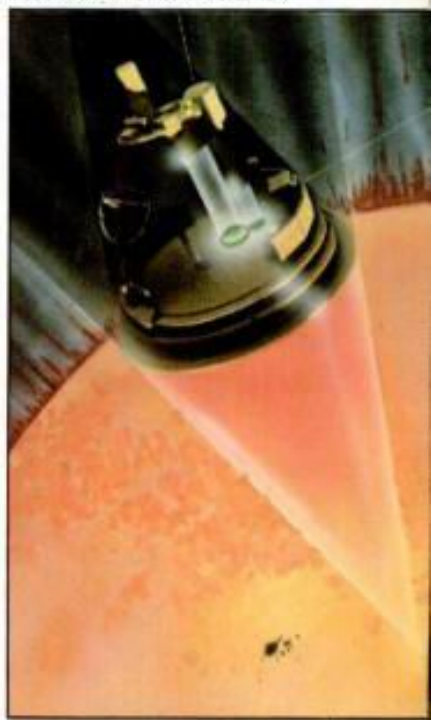
may be configured for use as laboratories, living areas and logistic transport. Boeing will also design internal environmental controls, propulsion systems and docking mechanisms for orbital transfer vehicles.

Martin-Marietta already has a leg up on the module design with its full-scale mock-up (above left). NASA currently is using the mock-up at Martin-Marietta's Michoud, Louisiana, facility to aid in planning the overall station.

Once upon a probe

Scientists at NASA's Jet Propulsion Laboratory are at work on Project Starprobe, a fanciful but plausible dream to send a probe into the Sun's corona. Despite the \$1 billion price tag and technological obstacles, NASA researchers have targeted the 1990s for launch. The craft (drawing at right), must withstand solar radiation 3000 times as intense as Earth's and temperatures about 1,150,000° F. NASA is testing carbon shielding at a unique solar furnace in France. Starprobe will come within 1,730,800 miles of the Sun—15 times closer than record holder, Helios. Starprobe's data will aid solar studies.

PM ILLUSTRATIONS BY BRIAN SULLIVAN



AGRICULTURE

Mobile fertilizers

Aeronautical engineer Moshe Alamaro has devised a novel approach to solving world hunger. Using his engineering knowledge, Alamaro is proposing to modify the old Birkeland & Eyde plasma arc furnace (photo right)—used during the '40s to produce nitrogenous fertilizer—to increase its efficiency and



yield. And, by transporting them to areas of need (drawing at right), cheap fertilizer could be produced anywhere there was ample electricity, air and water.





PM ILLUSTRATION BY ED VALIGURSKY

MILITARY

Soviets expand

The drawing above shows a Soviet Delta IV class submarine, the newest addition to the underwater fleet, breaking through the Arctic ice cap to fire a missile. The Delta IV represents a serious Soviet

effort to bolster its naval force. The Soviets launched the first Delta IV last year. The sub fires an SS-NX-23 ballistic missile with multiple warheads. Delta-class subs are viewed as a threat since they can hit North America from launching areas in the Sea of Okhotsk and Barents Sea, well out of reach of any known countermeasures. The Delta IV is undergoing sea trials.

New flares for choppers

Sophisticated ground detection methods are turning helicopters into fodder for heat-seeking missiles. But a new,

lightweight module, which can dispense up to 30 flares, may solve the problem. A CH-46 Chinook helicopter (below) fires infrared flares. The flares confuse heat-seeking and radar-guided missiles.



Avenger adds muscle

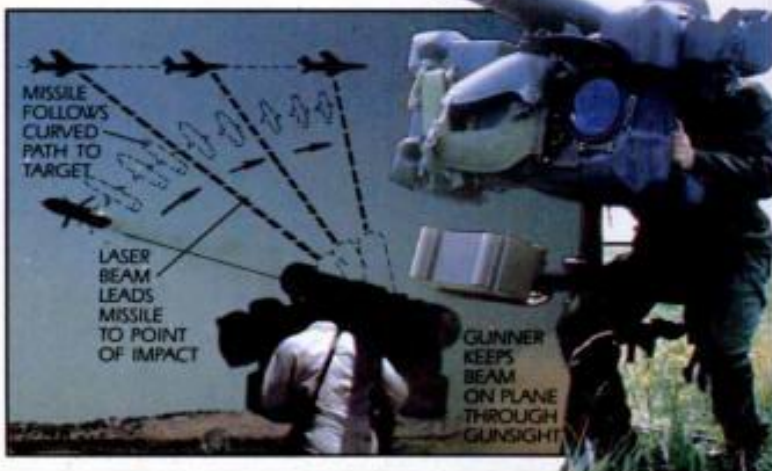
Boeing's added some muscle to its Avenger Mobile Air Defense System (photos below). The Avenger now has the ability to fire 2.75-in. rockets as well as ground-to-air Sting-

er missiles. Armed with a 7-rocket module, the Avenger is effective against light ground vehicles. The Avenger can fire Stingers while mounted on the Army's multipurpose Humvee truck, but a heavier truck is needed to fire rockets. The Avenger can accurately fire while rolling at 20 mph on an unimproved road. Its gyro-stabilized turret can carry and rapidly fire eight anti-aircraft missiles. It has automatic target tracking, friend/foe identification, rapid turret and reload action and day/night all-weather capabilities.

Missile rides laser

As long as the unit operator keeps his RBS-70 portable missile launching system aimed at an aircraft (below), a laser-line-of-sight system will guide the launched missile to the target. The RBS-70 can be

carried by three men and is effective against high-speed, low-flying attack aircraft. It's tripod-based to eliminate shoulder-fired weapon problems such as aiming, limited missile speed and limited range. The system takes only 30 seconds to set up.





American competitors may take on any of several designs shown in artist's conception. On this page, McDonnell Douglas AST (right) would fly at Mach 2.2. Lockheed's SCV (middle) would be slightly faster. A NASA concept (top) would reach almost Mach 3.

NEW BREED SSTs:

New engine performance, streamlined bodies and tough new wings will bring us an SST during the 1990s.

BY SHELDON M. GALLAGER
Illustrated by John Berkey

Today's SST, the Concorde, takes off at a sharp angle.

PHOTO: COURTESY
BRITISH AEROSPACE





While SST craft on facing page may fly in the 1990s, models depicted on this page are for the turn of the century. The Boeing Oblique Wing craft (top) could resolve lift and drag problems. The Hypersonic Scramjet (middle) could get up to Mach 7. And the Trans Atmospheric Vehicle (left) may exceed Mach 20.

SKY-HIGH MUSCLE

The snub-nosed airliner with its swept wings taxis down the runway like any other jet. It stands ready for takeoff, then flies away at such a sharp angle of attack it seems to be rising straight up like a rocket. Its scramjet engines hoist it over the ocean, where it breaks the speed of sound with a sonic boom. Now at full throttle, with its 250 passengers and crew pushed back in their seats by the growing gravitational force, the airliner reaches top speed as it approaches 100,000 feet. The pilot no sooner throttles

down, leveling off the jet, and it's ready for the descent. NASA's answer to the British-French Supersonic Transport (SST) is on its way from New York to Los Angeles—a one-hour trip.

Just 10 years ago, America's dream of building SSTs was shattered when Congress scrapped the project as too costly, too noisy and too marginal in the benefits it could bring. But today, the White House and Congress have given NASA a mandate to come up with the fastest airliner in the world by the 1990s.

NEW BREED SSTs

That would be an advanced SST. And, by the turn of the century, NASA and the aerospace industry are now reasonably expected to come up with a Trans-Atmospheric Vehicle (TAV) that skips the atmosphere at speeds approaching Mach 25 (see *Coming: A Mach 20 Airliner*, page 97, Nov. '84). Working with NASA on a variety of projects that add up to the SST of the future are Lockheed, McDonnell Douglas and a dozen subcontractors.

What suddenly makes an American SST an attractive prospect? The answer, according to a recent NASA preliminary report, lies in new technologies and materials not available when the British-French Concorde was built in the '70s. The European SST, which has outlived the operational life originally predicted by its critics, has undergone several modifications. But the real hope for a future American SST comes from an entire new breed of aircraft on the drawing boards and in the wind tunnel testing phase.

McDonnell Douglas is working on an SST that could be flying at Mach 2.2 by 1990. Dubbed the Advanced Superson-

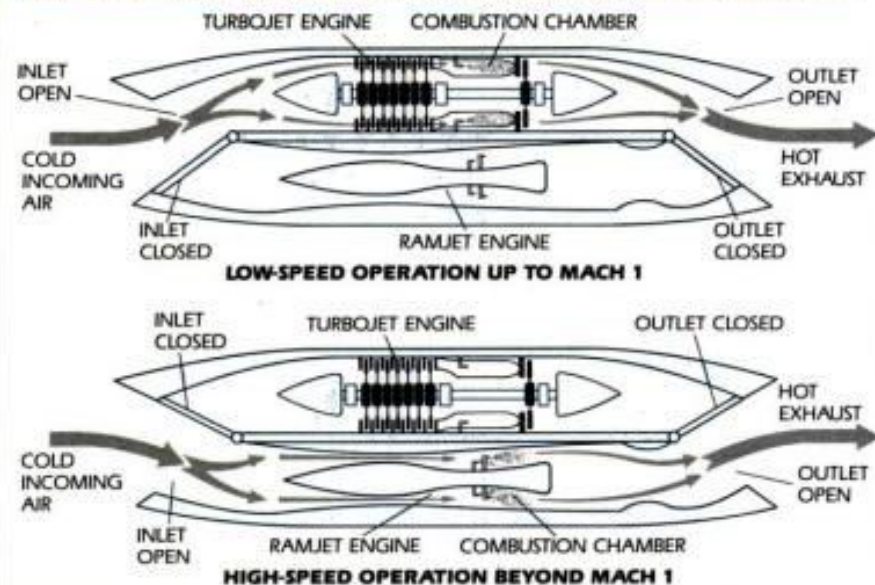
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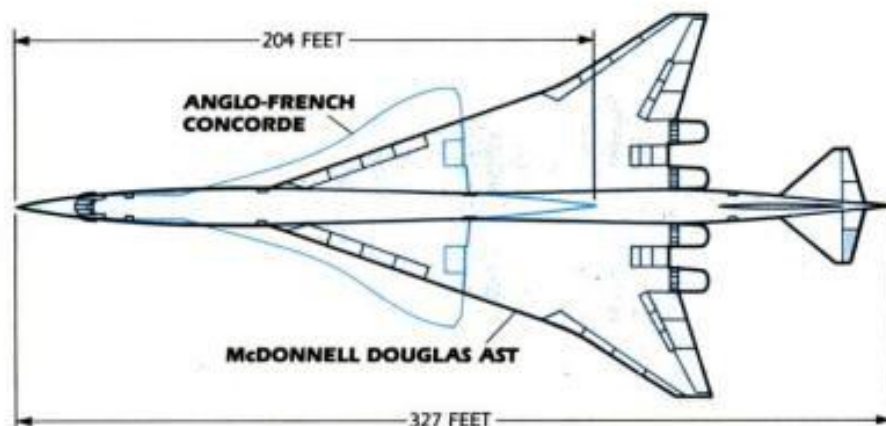
Delta wing SST (above) showed good lift but extra drag in wind tunnel tests. An advanced design (right) calls for a swing wing that can be angled sharply for high speed, or moved out to the wider delta position for subsonic flight.



TWO-IN-ONE ENGINE COULD HIT MACH 5 OR MORE



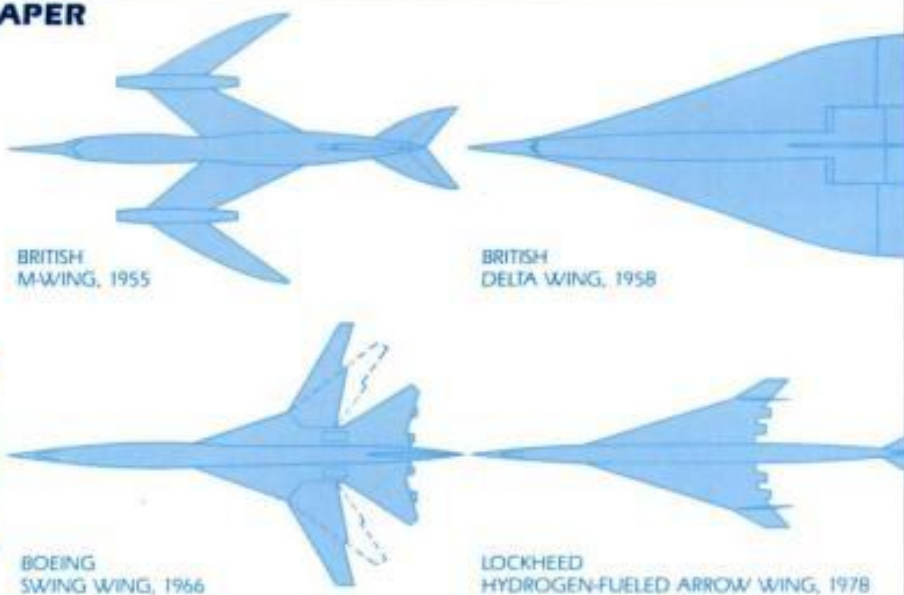
The over-under scramjet engine would operate on Mach 20 vehicle in painting at top. The engine works on turbojet or ramjet, as shown in drawing above.



THEY LOOKED GOOD ON PAPER



Early swing-wing model in wind tunnel tests was flyable but too expensive.



Wing design was a major stumbling block to early SST development. The M-wing stalled too easily, while others were unstable in flight.



COMRADES IN ORBIT

Even while Washington and Moscow go through cold war posturing, scientists are working up a co-op space mission.

BY LOUIS D. FRIEDMAN; Illustration by Brian Sullivan

I concluded my talk with a short sentence of apology: "Pro-
ceetye menya, ya govaru po-ruuski ochen mald." (Excuse
me, I speak Russian very little.) Then, the first question was
asked: "What about manned missions to
Mars—are there any studies in the U.S.
about this?" I laughed—because whenever I
give a talk in the U.S. mentioning Soviet plan-
etary missions, the one question I'm always
asked is, "What are the Soviets doing about
manned missions to Mars?" Now, here at the In-
stitute for Space Research, in Moscow, the mirror
image was being reflected. I was there as a guest of
the USSR Academy of Sciences to see preparations for the
Soviet Venus-Halley spacecraft, and to discuss international
cooperation on future exploration of the solar system. The So-
viets hosted me for an extraordinary week—an opportunity
made possible by Soviet academician Roald Sagdeev, director
of the Institute, a man devoted to the international peaceful
and cooperative exploration of space.

In part, my trip was the result of The Planetary Society's
program to promote international projects for solar system

*Louis D. Friedman is executive director
of The Planetary Society, a California-
based group that conducts space research
and encourages planetary exploration.*

American astronauts and Soviet
cosmonauts would work side by
side from an orbiting space station
around Mars. Station would be
composed of parts from both
countries and European partners.
Our concept art shows lander
leaving for Martian surface.

COMRADES IN ORBIT

exploration. Dr. Sagdeev is an adviser of the Society, and I like to think that my participation was a recognition of a small part I had played while I was at NASA's Jet Propulsion Laboratory with another Society adviser, Prof. Jacques Blamont of France, identifying trajectory opportunities which resulted in the Venus-Halley mission. (Of course, we were trying to define a mission for a U.S. visit to Halley's Comet.)

It doesn't take a written or acknowledged policy to know that a manned Mars expedition is where the United States and the Soviet Union are heading in space. It would be most sensibly done as a project of Earth, by all space-faring nations. This requires the cooperation of the two leading such nations—the U.S. and the USSR.

The first handshake

Ten years ago, at 4:09 p.m. GMT, July 17, 1975, the principle of such cooperation was established when two spacecraft rendezvoused and docked 222 kilometers above the Earth. A few hours later, Astronaut Tom Stafford and Cosmonaut Aleksei Leonov shook hands and visited each other for dinner

proved to be of scientific value and of mutual benefit—if not to the decided advantage of the United States.

The Soviets' capability to maintain human life in Earth orbit, their study of the effects of long-duration space flight on crews, and their impressive series of landing and exploration at Venus have given them a decade of achievement at least equal to that of the United States. And in all of these activities they have shared their science and knowledge with us, teaching us much in important areas we would have otherwise known little about.

Even during times when most exchanges were stopped between the two countries, American and Soviet scientists have continued to meet and exchange data about such important factors as motion sickness, calcium loss in bones and the ability to adapt to weightlessness. Recently, a cooperative experiment was conducted by the two nations to measure bone mass in cosmonauts before and after the long Salyut flight.

In the planetary program, Soviet Venera radar images have been given to U.S. scientists planning the Venus Radar Mapper mission for 1988. As a result, the specifications for the U.S. mission have been altered, and improved results are expected. In addition, several U.S. scientists have been invited to participate on the Venus-Halley Mission (called VEGA in Russian) and other future missions.

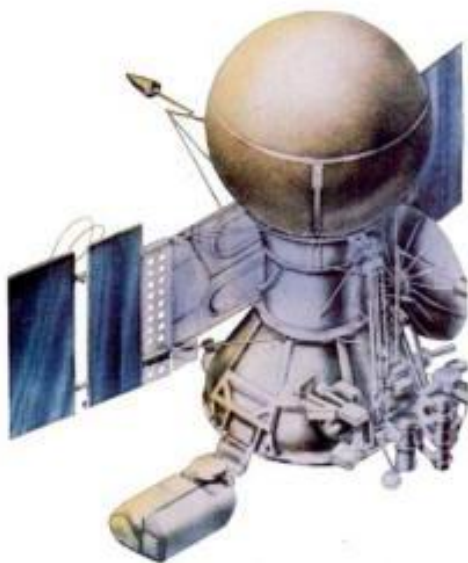
Recently, the U.S. proposed a joint USA-USSR simulated space rescue mission. The idea is to have the Space Shuttle rendezvous in orbit with the Salyut, the Soviet space station, to practice rescue operations. Such operations might include extravehicular activity by astronauts and cosmonauts.

Political differences have prevented this proposal from being advanced thus far. One difficulty is the Soviet posture stating that the Shuttle is a military vehicle. Another may be a desire by the Soviets to have their own shuttle operational before agreeing to a joint operation in Earth orbit. A Shuttle/Salyut mission would be of value in the near term to prove the feasibility of space rescue and in the long term to provide additional capability for human activity in space.

Nations in space

International cooperation is already an intrinsic part of Earth's exploration of the solar system. Of the 13 spacecraft now in flight, or planned, to explore beyond the Earth, seven carry more than one nation's contributions, and all

(Please turn to page 132)



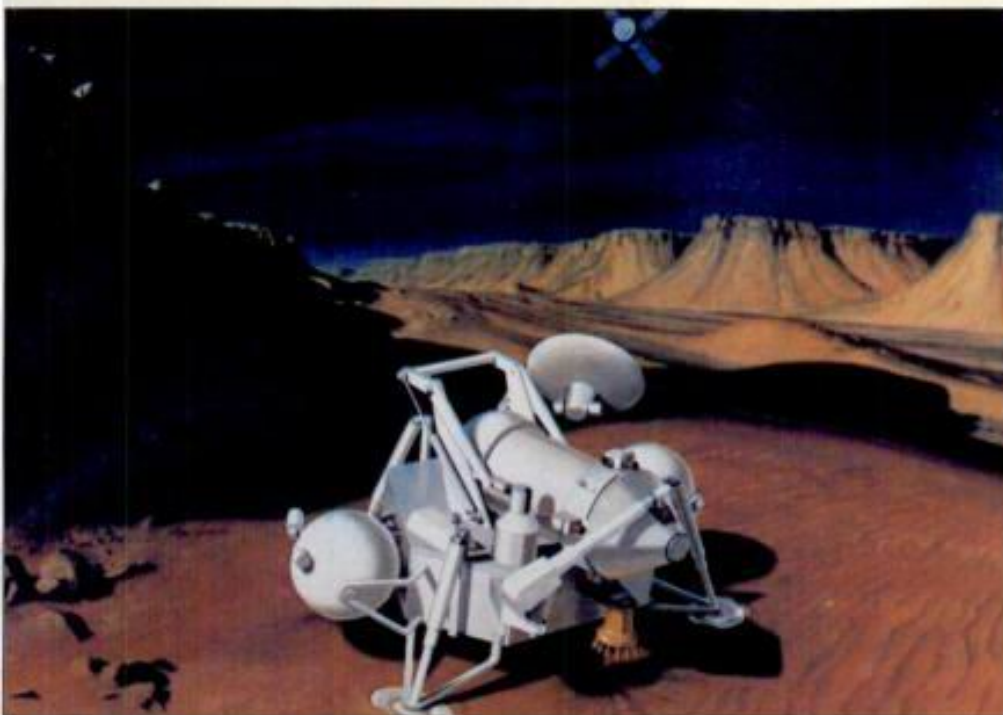
Concept art of an interim planetary explorer shows craft that could perform mapping and other missions in the 1990s.

in their respective spacecraft: Apollo and Soyuz.

Critics called the Apollo-Soyuz mission a stunt, a billion-dollar handshake, or worse yet, a billion-dollar close-up look at our technology for the Soviets. But now, looking back from a perspective of 10 years, we realize that this was a first step in changing space from an arena of chauvinistic competition, to a place for international cooperation in exploration. Such cooperation has



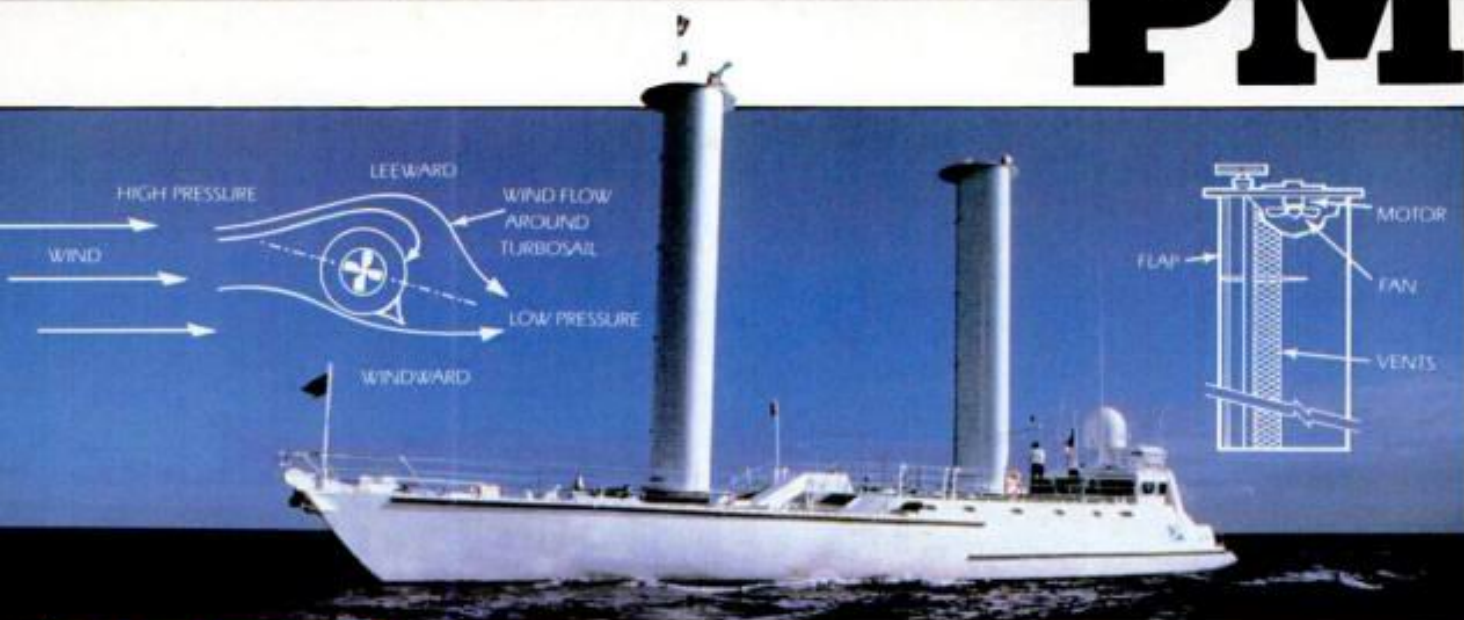
ILLUSTRATION BY PAMELA LEE



COURTESY THE PLANETARY SOCIETY

In the 1970s, Americans and Soviets shook hands at the Apollo/Soyuz docking (above). Future missions may include a Soviet-American polar exploration of Mars (far left), following a robot lander exploration (left) using technologies of both countries. One 21st century mission suggested in a report to The Planetary Society would be a multinational landing on the Martian moon Phobos, visualized below. A dozen nations are already interested in such a mission.





PM ILLUSTRATIONS BY GEORGE BETSECK

MARINE

Yes, those really are sails

Foundation Cousteau has completed the *Alcyon* (above) with its cylindrical Turbosail propulsion system. The

units are hollow, with suction vents on both sides. A fan on top of the cylinder draws air through the open leeward side

to create a lift-pull effect. Windward vents are covered. Turbosail flaps are orientated by a shipboard computer.



'Phoenix' fireboat seeks to prevent creation of ashes

The world's first catamaran fireboat, the *London Phoenix* has assumed duty on the Thames River with the London Fire Brigade. *Phoenix's* twin hull draws only 5½ feet of water despite a 51-ton displacement. The craft's wide

beam provides a level table for its hydraulic platform and its six water cannons, which deliver 4500 gallons per minute. Twin 317-hp diesels propel the *Phoenix* to 11½ knots. It will be used to negotiate shallow tidal water.

SOLAR POWER



Sun shines on winners

Although Europe's 5-day, 228-mile Tour del Sol rally for solar-powered vehicles had

one winner (Mercedes' Silver Arrow, see *Technology Update*, page 80, Dec. '85), there were many technological winners. Following closely on Silver Arrow's heels was the Biel (below), fielded by a Swiss technical college, with 428 photovoltaic cells. First in the hybrid category was the muscle-aided Globi (above), a pedal-solar craft weighing in at a lithe 186 pounds. It attained a speed of 21 mph. The technologies will find practical uses later.



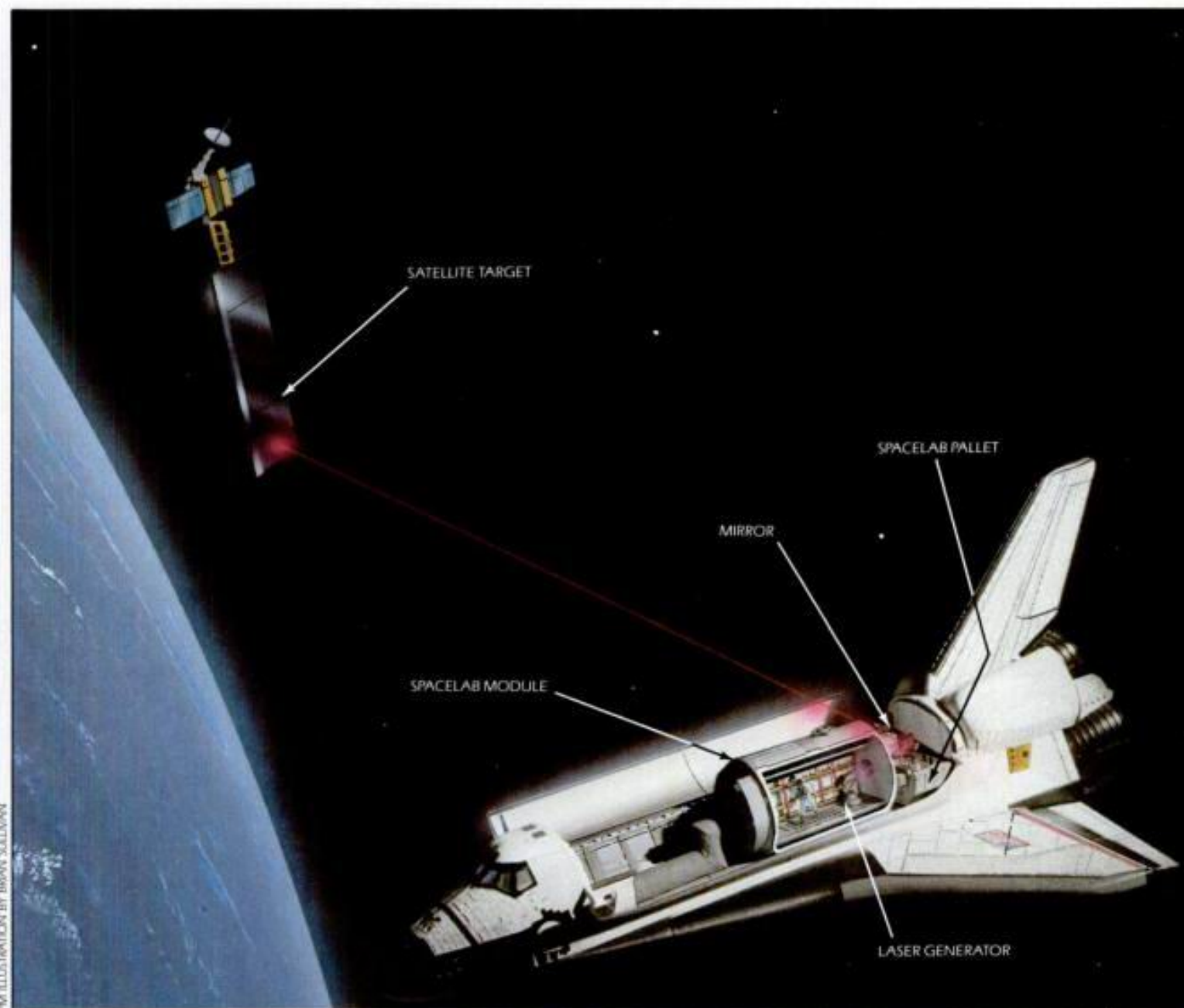
AGRICULTURE

Less work for farmers

The Lightspray 1048 is lighter, faster and more fuel-efficient than a tractor of comparable proportions. Despite its large 230-gallon tank, the British-built vehicle exerts low, even pressure and can spray at

speeds up to 15 mph. Special suspension joints keep the 40-foot stainless-steel booms steady. Lightspray is powered by a 1600-cc engine with an 8-speed gearbox and can also be used for applying micro-granules and granular fertilizers. Farmers can treat crops and soil very quickly with only a minimum of ground damage to their land.

PM TECHNOLOGY UPDATE 2/86



PM ILLUSTRATION BY BRIAN SULLIVAN

'Star Wars' laser to undergo test

Laser beam tracking and firing will be tested on board the Space Shuttle sometime this year by the Strategic Defense Initiative (SDI) space-based missile defense program.

SDI has reserved the Shuttle and the European-built Spacelab module to demonstrate tracking and

pointing capabilities necessary for future U.S. satellites to destroy Soviet ballistic missiles in flight. During the mission, laser beams fired through a window in the Spacelab module will strike one or more large mirrors mounted on a Spacelab pallet, then be reflected toward satellites or other targets.

Targets that are under consideration include the German ERNO SPAS Shuttle pallet satellite released during mission seven or the Goddard Space Flight Center Spartan satellite used last June. Researchers are also considering aiming the beam earthward where ground-based sensors could deter-

mine the potential for actual battle lasers which would engage Soviet missiles shortly after lift-off, while the warheads are still in the lower reaches of the atmosphere.

Editor: Dennis Eskow
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WORKING SPACE

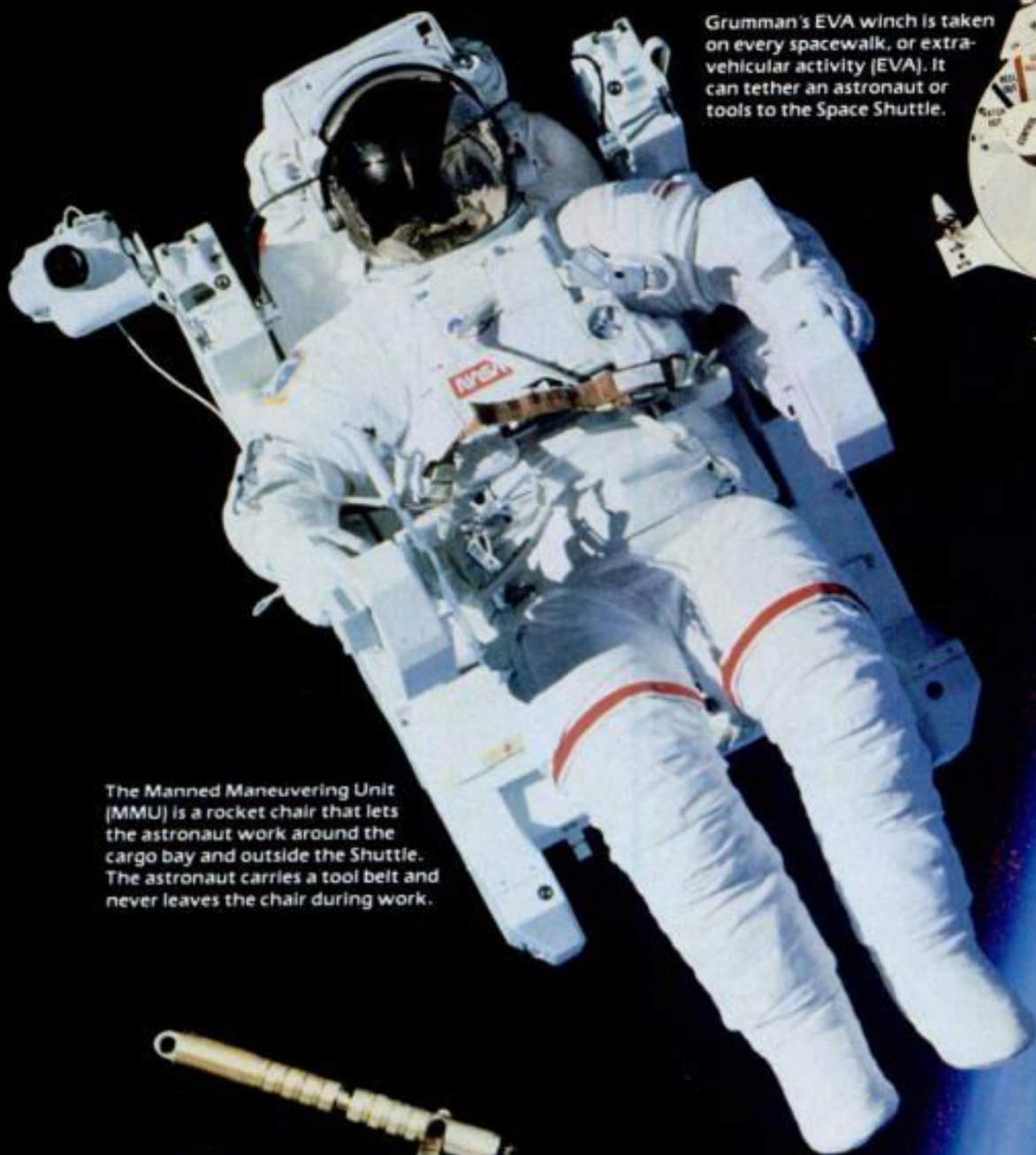
You're weightless.
You're moving at 17,000 mph.
And you'd better get the job
done right the first time.

BY BRUCE FRISCH

As Shuttle pilot Joe Engel triggered a few short rocket bursts to edge away from the repaired Leasat 3 communications satellite, a shiny silver object floated out of the cargo bay. A new, inadvertently launched "satellite" called EVA Power Tool entered into orbit. Repairmen "Ox" and "Fish"—Dr. James D. van Hoften and Dr. William F. Fisher—had laid the battery-powered drill inside the open airlock between the cabin and cargo bay just in case they needed it. Like many divers who've watched tools and camera lenses sink out of view, they had not tethered it.

In many other ways, working in space is like working as a diver. In fact, to duplicate orbital weightlessness, astronauts rehearse their spacewalk assignments in a large tank at Houston's NASA Johnson Space Center using repair techniques often worked out in other tanks at NASA Marshall Space Flight Center in Alabama, McDonnell Douglas Astronautics in California and the Massachusetts Institute of Technology. Both divers and astronauts depend on an artificial air supply, attach checklists to their wrists, have worklights on their helmets and voice communications to the surface, and wear a suit and

James D. van Hoften and William F. Fisher work on a satellite docking device in the Space Shuttle cargo bay. On most missions, the astronauts use 150 or more tools to do space repairs and experiments.



The Manned Maneuvering Unit (MMU) is a rocket chair that lets the astronaut work around the cargo bay and outside the Shuttle. The astronaut carries a tool belt and never leaves the chair during work.

Grumman's EVA winch is taken on every spacewalk, or extra-vehicular activity (EVA). It can tether an astronaut or tools to the Space Shuttle.



The centerline latch tool has a variety of uses in orbit. It serves as a clamp, crimping tool and pliers in repair work, and has even been used to open hatches.



MARINE

Foiled in Germany

Airfoil technology has gained popularity in the military and in Scandinavian

countries where you need a vehicle that can move swiftly over sea and land. But the airfoils currently in operation are on a small scale compared to those being created by two West German inven-

tors. Gunther Jorg and Hanno Fischer have each built prototypes in competition for a West German government contract. The ultimate prize is the building of a 400-passenger craft with a 1000-

mile range that can travel at speeds over 120 mph. A Jorg prototype is shown in the inset photo above. West Germany is expected to have in operation the world's largest airfoil by 1990.



MILITARY

Brazil's tank

Brazil has cut itself loose from one old tie with Washington with the introduction of its Main Battle Tank. The Brazilian Osorio is a 40-ton

tank designed to work with a range of guns. With the Osorio, the U.S. now has a competitor in the Third World. The Osorio, by the way, can carry Soviet-made cannons and rocket-launching devices.

New Army truck

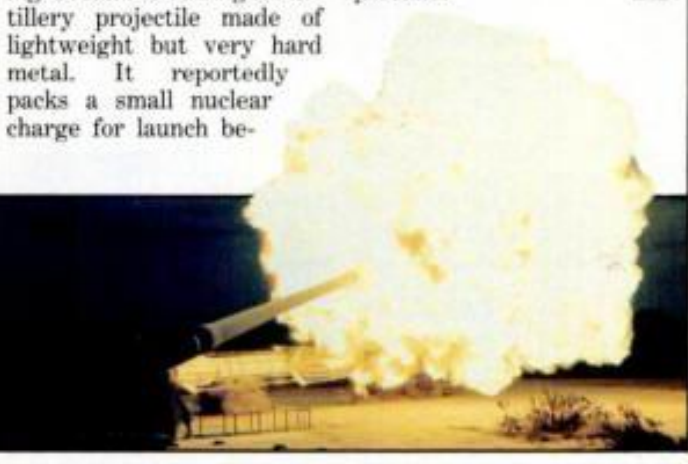
Both the Army and Marines have begun replacing their 6x6 truck fleets with new 8x8s from Oshkosh. The Ma-

rine version, dubbed dragon wagon, can be lifted by helicopter. The Army's "straight eight" is not helicopter ready, however the truck is lower-priced and easier to maintain.

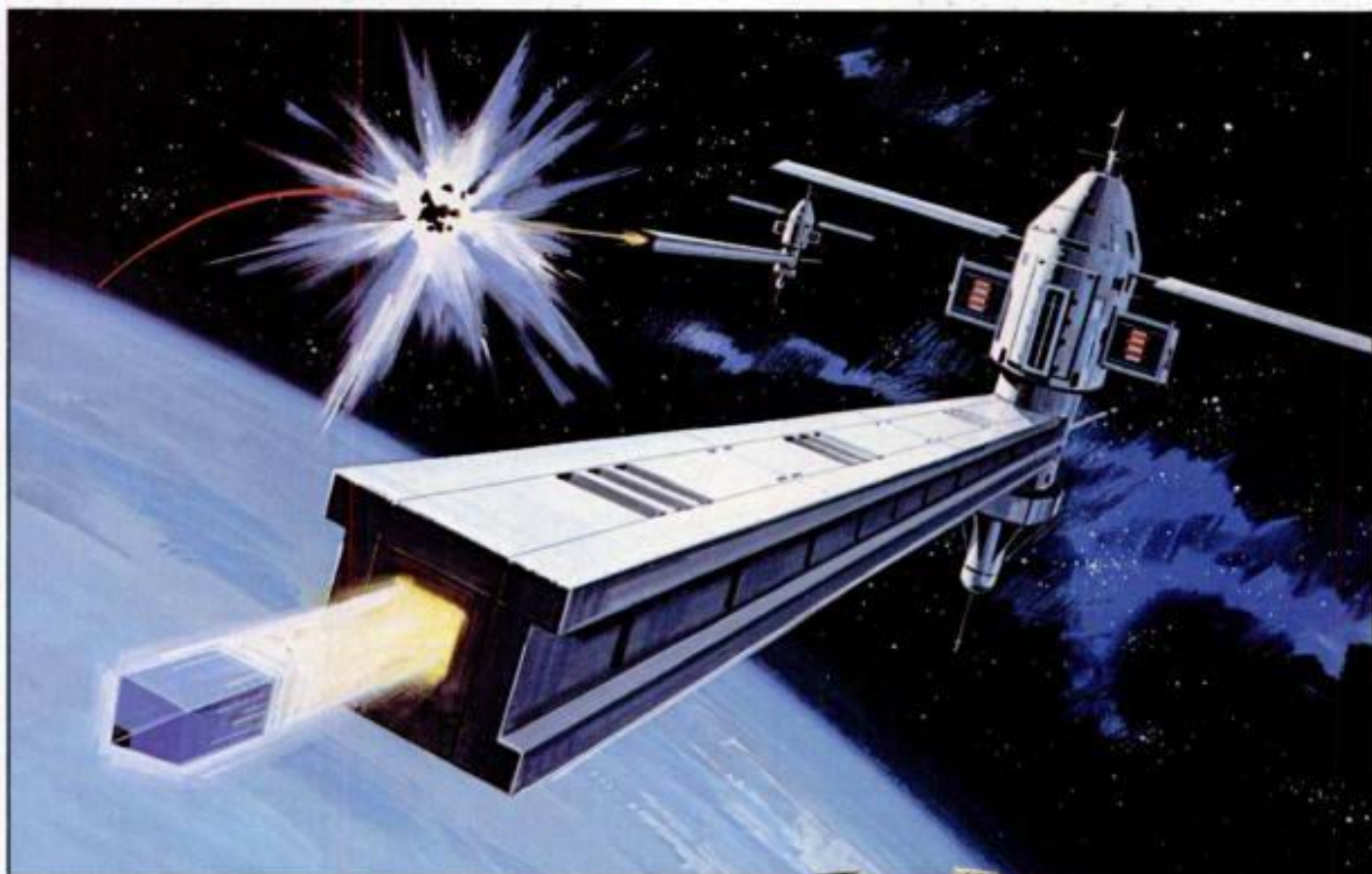
Tight shot

The Army's Aberdeen Proving Ground is testing an artillery projectile made of lightweight but very hard metal. It reportedly packs a small nuclear charge for launch be-

yond the range of the nuclear blast. That could make localized nuclear combat more possible. **TU**



PM TECHNOLOGY UPDATE 6/86



PM ILLUSTRATION BY ED VAUGHAN

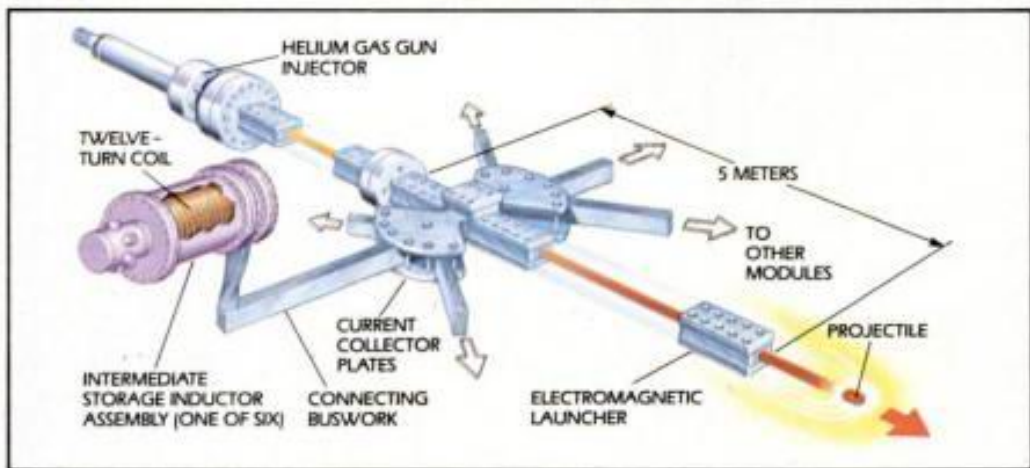
Quick on the draw

Checmate Railgun is an electromagnetic launcher, the latest space cannon for the Star Wars defense arsenal. Floating in low-level orbit, a scout satellite can spot the flash of any attacking missile. Its railgun fires. Stored high-intensity electric power is transferred to the projectile as it leaves the rails, or barrel, of the gun. This charge becomes a hyperboost of kinetic energy, speeding the bullet at over 2 miles per second. Because of this incredible speed, at the target the 3-ounce shot has the impact of a freight train. Any offending missile would

be smashed out of the sky as it began to climb, a minute or two after its launch. Pentagon leaders argue that development and deployment of railguns like Checmate will prevent any surprise enemy missile attacks.



Checmate Railgun (above) zaps enemy spacecraft or can stop a missile as it is launched. Operating model (left) at Maxwell Laboratories in California tests this kinetic energy weapon. Concept (below) is to charge projectile with electrical power as it speeds out of railgun.



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PM ILLUSTRATION BY HANK KERN



PM ILLUSTRATION BY ED VALIGURSKY

MARINE

Underwater spy

There may be more than just fish snooping about down in the world's oceans. A new military toy from Great Britain is already in swimming

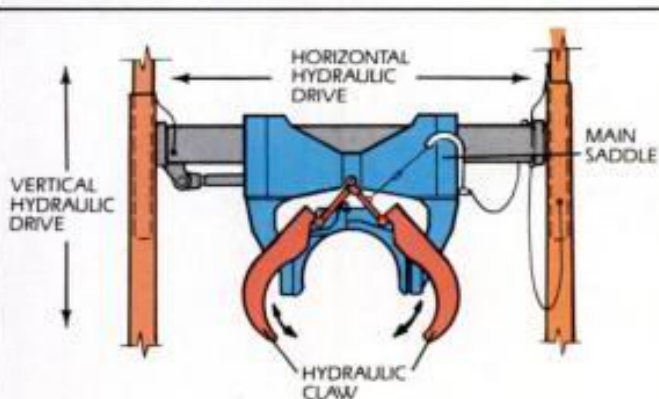
prototype. The Seicon Patrolling Underwater Robot (SPUR) can navigate autonomously and communicate electronically to tattle or

take orders. While mainly a snoop with its lights, videos and radar, SPURs could deactivate mines or carry torpedoes or explosives.

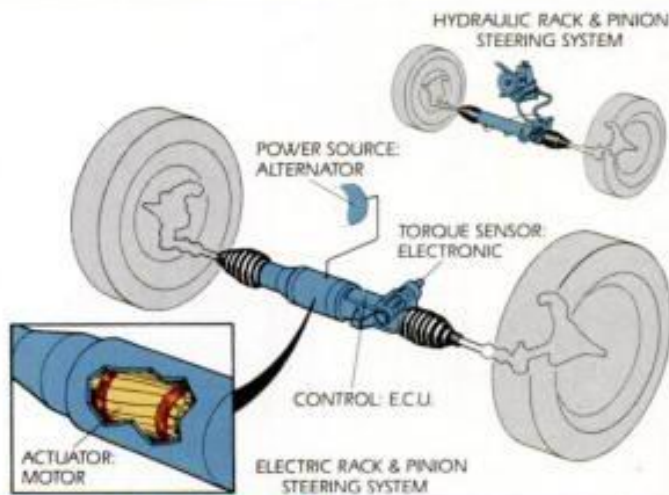
Underwater workshop



SUPRA, a German seagoing prototype is a robot, a mini-submarine, a diver's workshop and an underwater derrick. By remote control or with a crew of two, it can perform heavy underwater jobs, lifting up to 20 tons, that until now required surface ships. For pipeline laying and repair, SUPRA's claws (below) will make quicker, better work beneath troubled seas.



PM ILLUSTRATION BY ED LIPINSKI



AUTOMOTIVE

Electric steering

TRW may have borrowed from its sophisticated aerospace and military designers to develop this new, simple electronic steering system for the ordinary automobile.

This modular system weighs and costs less, but is more responsive than conventional hydraulic power steering. The actuator, torque sensor and rack-and-pinion drive are faster than a human driver, and the system does away with the belts, fluid, pumps and hoses of traditional steering.

PM ILLUSTRATION BY HANK KEN

TECHNOLOGY UPDATE 7/86

AVIATION

Super Concorde

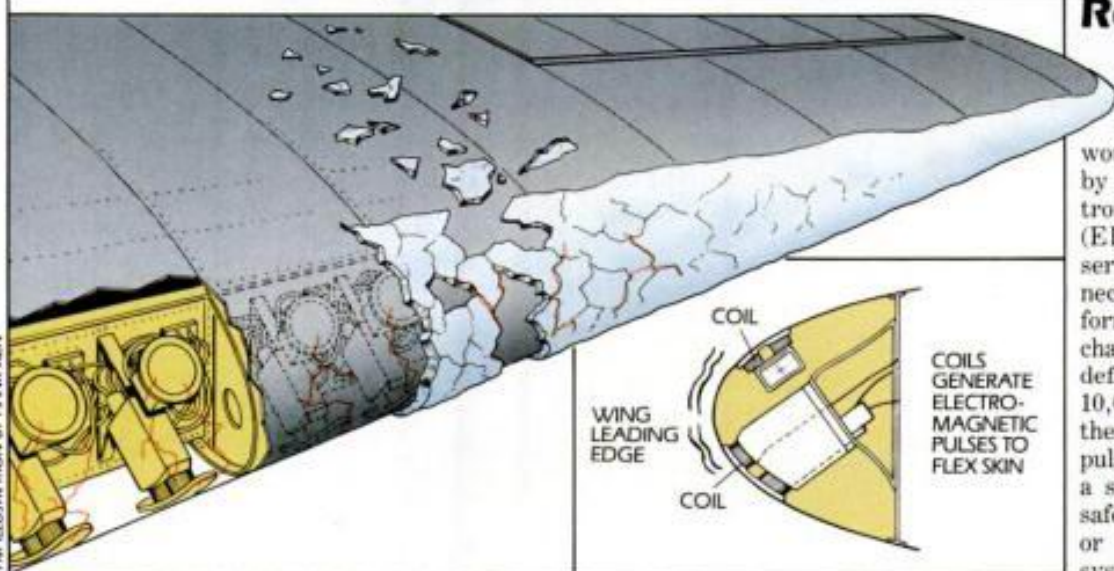
While many aerospace companies are talking about SST prototypes, a second-generation Concorde model is being tested by Aerospatiale. Due by 2000, the new Concorde will be faster, larger and twice as fuel efficient. The 200-passenger craft will have variable-cycle engines with a bypass mode for slower subsonic flight. Digital technologies and computer screens will do most of the work, as only a 2-man crew watches the cockpit.



PM ILLUSTRATION BY ED VANGURSKY

Removes ice electrically

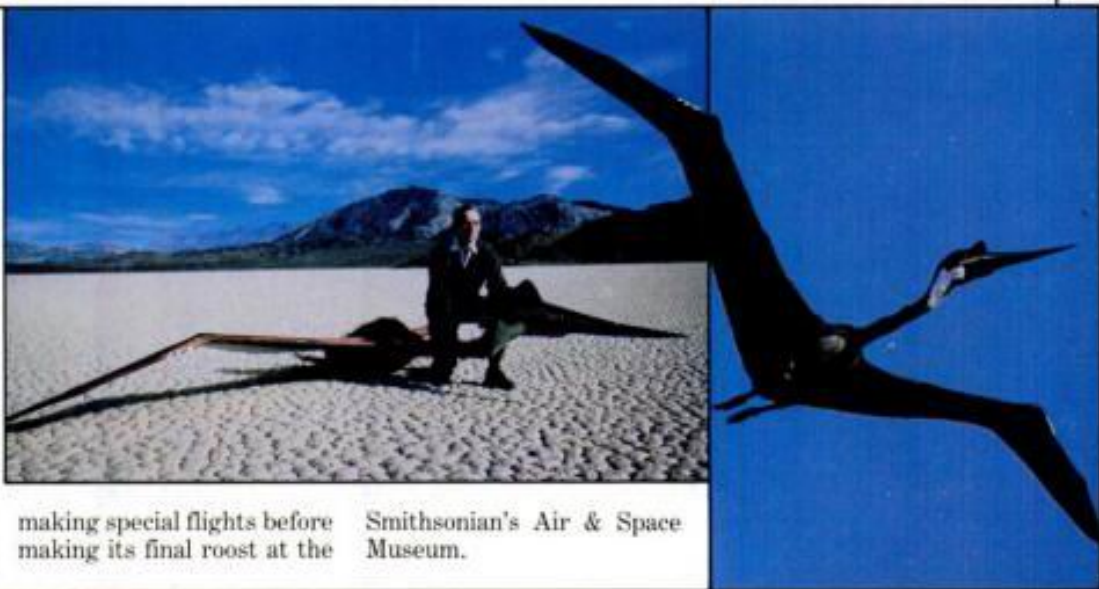
A new system being developed by NASA would fracture in-flight ice by electric shock. This electromagnetic impulse deicing (EID) system consists of a series of copper coils connected to high-voltage transformers. A millisecond's charge causes a leading-edge deflection with a force up to 10,000 G. In tests, a couple of these shock waves, or pulses, will completely deice a surface. EID is fast and safe, without the corrosion or fire danger of chemical systems.



PM ILLUSTRATION BY HANK KEN

An old bird flies again

The prehistoric pterodactyl flaps in the sky again with battery-powered muscles and an onboard autopilot. Paul MacCready's half-scale high-tech model is 18 ft. between wingtips but simulates the skin, feathers and flight abilities of the giant birds of 65 million years ago. By combining aerodynamics, electronics and paleontology, scientists can unlock the flight recorder of the past. Created from fossil details, MacCready's bird has been



making special flights before making its final roost at the Smithsonian's Air & Space Museum.



AMERICA'S ORIENT EXPRESS

Within the next 10 years, we may be able to fly
from New York to Tokyo in about two hours.

BY GEN. CHUCK YEAGER, USAF (Ret.)



Proposed Orient Express plane will skip the atmosphere using huge scram-jet power plant.

Sitting in the cramped confines of the Bell X-1 at 42,000 ft., I felt every shake, rattle and roll, and then the sonic boom that announced man's first encounter with Mach 1. It was thrilling. We were crossing an unknown barrier.

That was 1947. Today, thousands of airline passengers fly at Mach 1 and more every week aboard the Concorde. Somebody asked me what happens to a man at Mach 1. Nothing. How about Mach 2? Nothing still. How about Mach 25? The answer is still nothing. And I'm sure man can push himself all the way to the speed of light, sitting comfortably inside a well-outfitted aircraft. That's why I was not at all surprised earlier this year when President Reagan announced his support for the X-31, the aircraft of the future he calls the Orient Express.

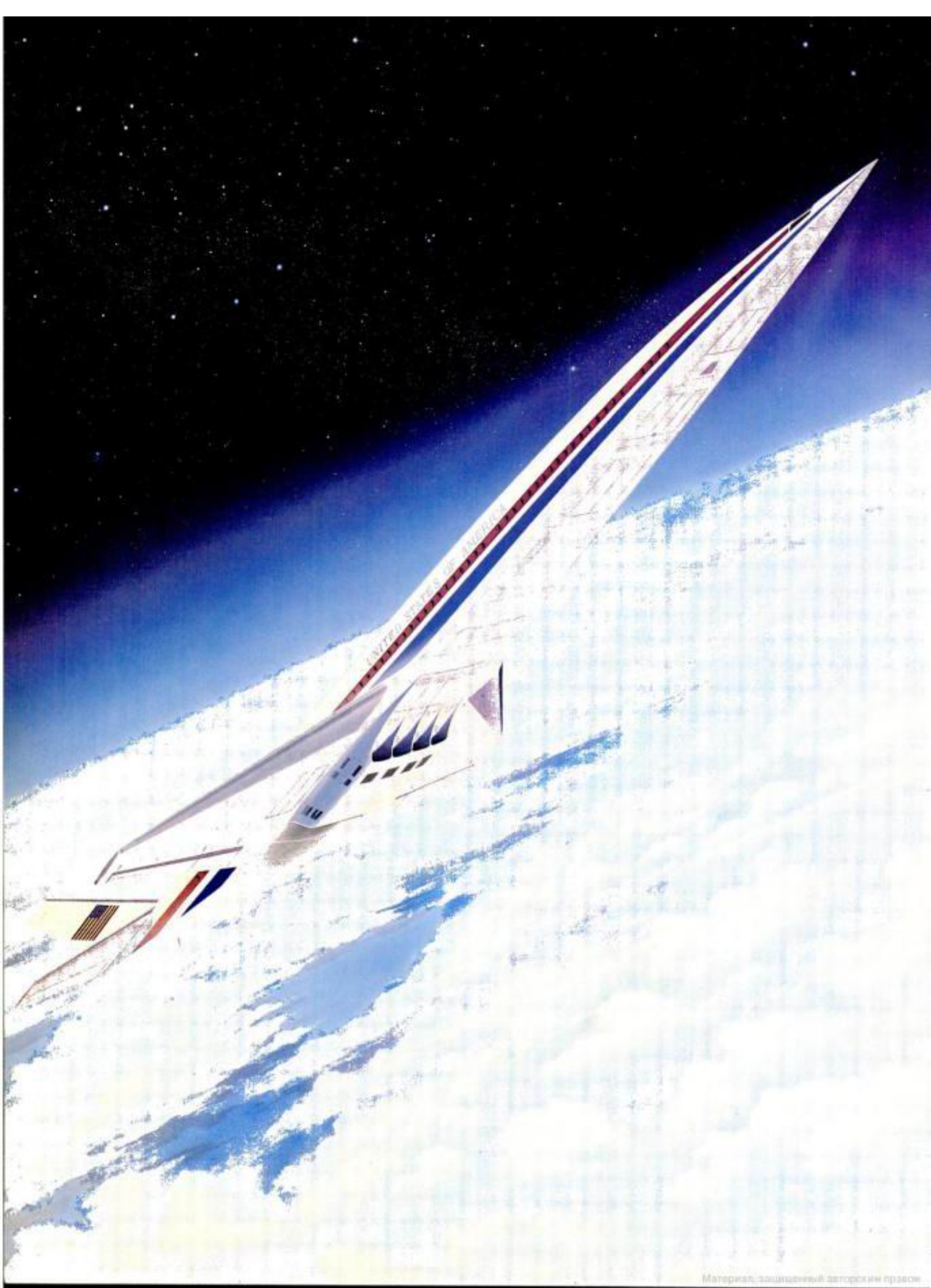
Within a decade, we will have a plane that can fly the route from New York to Tokyo in about two hours. And, if the airlines think they can sell seats economically, there is no reason why we won't have scheduled flights from coast to coast running less than an hour. In fact, Northwest Orient airlines, the largest U.S. carrier to the Pacific, has already announced that it would be a customer.

The Orient Express is President Reagan's word for

what the Air Force, Defense Department and NASA have for several years called the space plane. All the technologies to build a Mach 5 plane immediately, and a Mach 25 plane before the turn of the century, are in place. The pieces just have to be put together. That will happen over the next five years as we develop the X-31 test plane. It will be used to demonstrate new propulsion technologies, advanced metals and aerodynamic designs.

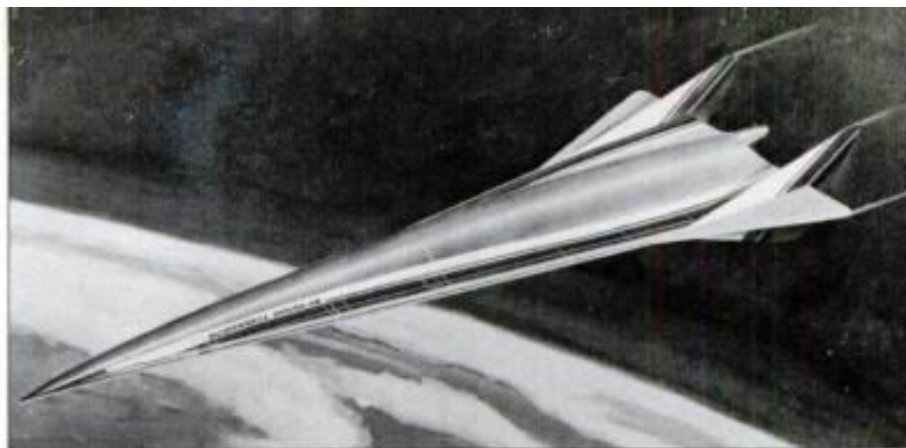
Until recently, the chief barrier keeping us from building an Orient Express was the powerplant. In the 39 years since the sound barrier was broken, we've flown above Mach 3 with jet aircraft. The fastest jet plane in the air is the SR-71. It flies a little faster than 2000 mph, which is Mach 3. To get beyond that speed, a new technology—tested in ground-based labs, but not yet in the air—may provide the first important leap forward. It's called the air turbo-ramjet. Aerojet Techsystems has one that has been ground-tested successfully. The air turbo-ramjet burns hydrogen fuel. The exhaust powers a turbine that drives a compressor. Air forced into the system is relatively cool, so there's no danger of the turbine blades breaking up.

McDonnell Douglas has taken a keen interest in this engine technology, and aerospace engineers feel it could



The scramjet engine will take up much of the underbody of the Orient Express plane, as shown on the facing page. The engine will operate in different phases, from a jet on takeoff to a rocket in flight. McDonnell Douglas is working on a concept using needle-nose dynamics (right). A Lockheed concept for the Orient Express (below) resembles the U.S. Space Shuttle.

FACING PAGE ILLUSTRATION BY MARK McCANDLISH



be the first Orient Express engine. It would provide enough power for Mach 5 flight at atmospheric altitudes. Several other aerospace firms are looking at variations to the theme, and General Electric has lately indicated an interest in developing this next generation jet. If McDonnell Douglas started work on its Mach 5 plane today, it could be flying passengers in 1992.

Meanwhile, NASA researchers are working on a next-generation Orient Express engine called the scramjet. Various designs have been proposed, but the point of any scramjet is always the same—to shape shock waves. The scramjet engine, to keep a plane flying at Mach 8 and beyond, would have to withstand intolerable temperatures. The engine could be kept at a steady cool temperature, however, if air moving at supersonic speed could be forced through the system.

Of course, air moving at supersonic speeds produces shock waves. The way around that problem is to have a very broad inlet to the scramjet, and build its insides shaped to accept shock waves. NASA, Air Force and McDonnell Douglas concepts of a scramjet-powered plane call for the entire underbelly of the aircraft to be an intake. The design has worked in computer simulation. Now it has to go to the technical demonstration phase.

Ideally, the Mach 25 plane of the next decade would take off in a simple tur-

bine mode, bypass to an air turbo-ramjet mode, get into the upper atmosphere in the scramjet mode and leave the atmosphere as a chemical rocket. The multipurpose engine will give the pilots options in different weather conditions and at different altitudes.

As we move toward Mach 25, major changes will have to be made in airframes. They will have to be as lightweight as possible, but also be able to take extreme stress from temperature, pressure and gravitational forces.

Inside the Orient Express, be it a Mach 5 craft or a Mach 25, I foresee no major changes. The basic design of today's aircraft would be comfortable at any speed. Although the Orient Express will be traveling at dizzying speeds, the passengers inside will be standing still in relation to the aircraft.

It is likely that a future Orient Express, in operation by the late 1990s, would operate as a Trans-Atmospheric Vehicle (TAV). It would take off horizontally, like an ordinary aircraft, sweep up into the high atmosphere at Mach 8 or so, leave the atmosphere and speed up to Mach 25, then slow down as it made its landing.

The flight of a TAV, like the typical New York to Washington shuttle jets of today, would be mostly takeoff and landing. Less than half the trip would be spent in level flight.

One technology which is lagging today and which will have to improve in

the future is that of airport construction. The Orient Express probably will operate only out of major cities. There's no time, or need, to go Mach 8 on a flight from Las Vegas to Los Angeles. So only a few specialized airports would need to be built.

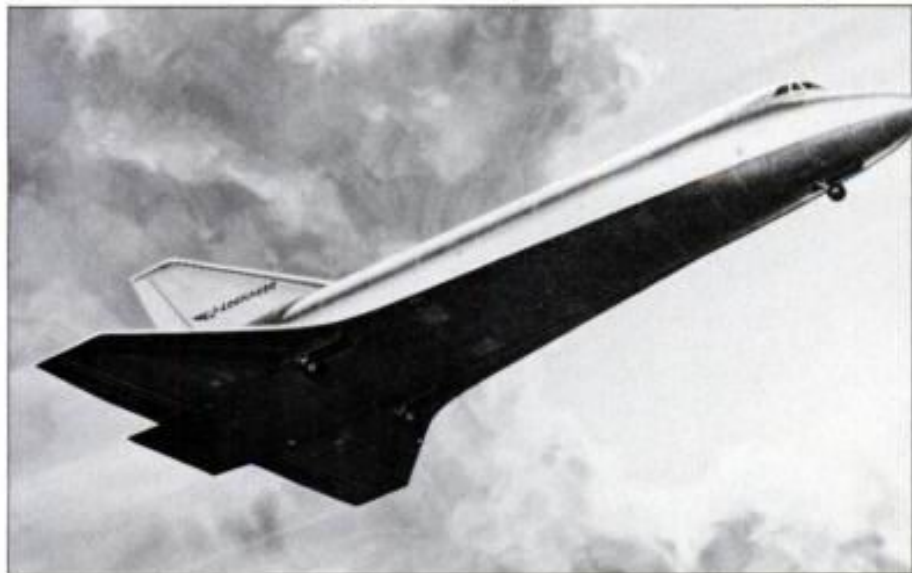
I can envision a new floating airport built on an artificial island off New York City. And the Japanese already have such an airport planned for the Tokyo area. The main reason for a new airport for the Orient Express is that it would need more landing strip than today's airports have. International airports give today's jets nearly 2 miles for takeoffs and landings. The Orient Express likely will need a landing strip of about 3 miles.

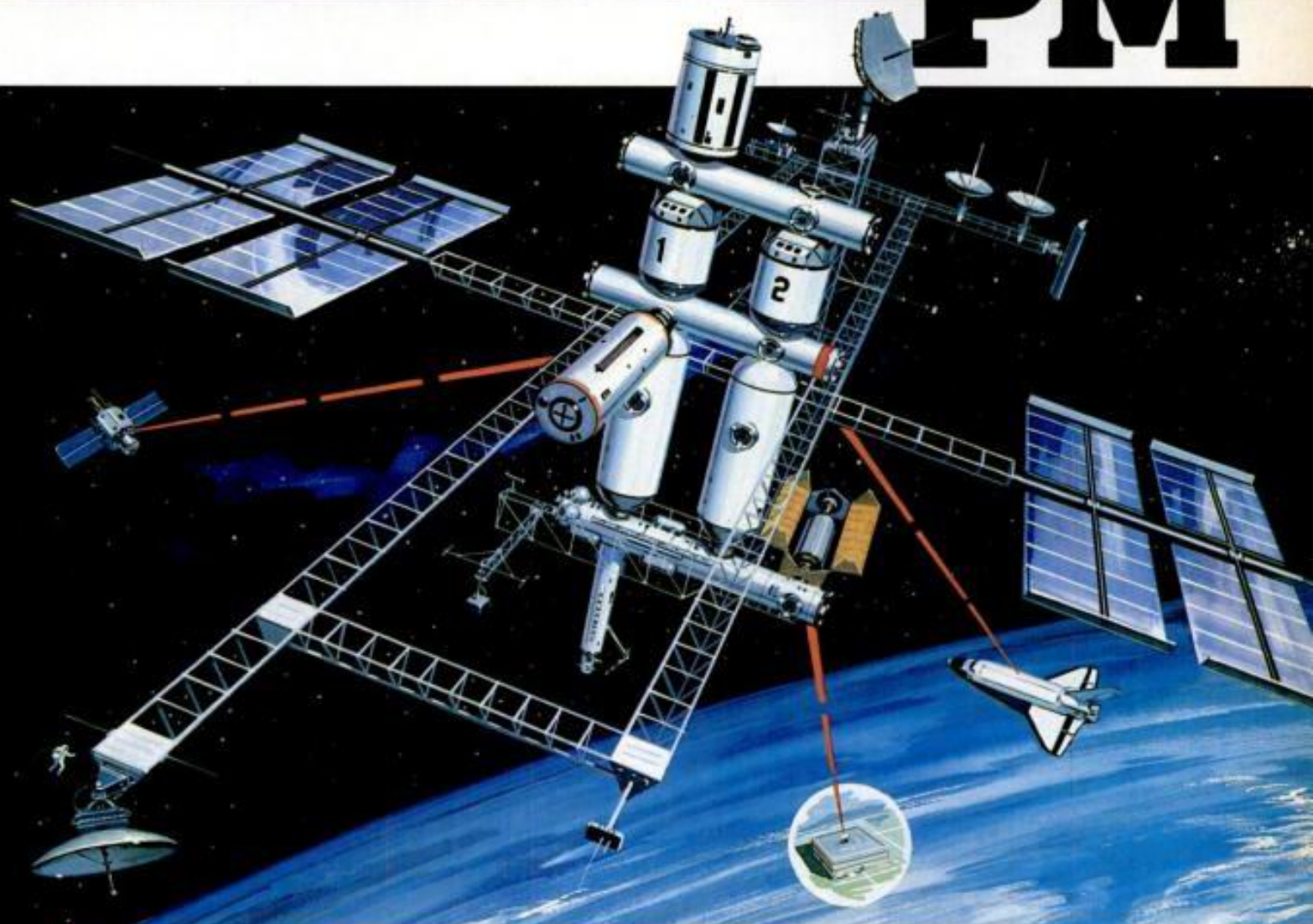
The building of new airports for these aircraft will enable us to explore a technology we have ignored—building airports that make sense. Today's airports take almost as much time just to get to as the flight itself takes. That makes no sense. Many of the current airports don't have enough runways. New airports for the Orient Express can address that dilemma as well. And new airports, especially offshore projects, could be more environmentally sound, too.

The technology to develop the X-31 aerospace plane is available today. Within five or six years, that plane will be running what amounts to shake-downs of the engine and airframe technologies.

Somewhere between now and the first flight of the X-31, I expect the airlines are going to take a serious look at the possibilities. Whatever they decide at the present, we will have to push ahead with the research. Consider the ground we lost when Congress cancelled the U.S. SST a decade ago. Today the French are building a second-generation SST. We still have none. Last year, Congress finally came to the conclusion that we should have continued research into commercial supersonic flight, and it authorized NASA to research a potential American SST. With the coming of the Orient Express, the French SST should become obsolete. And the Orient Express will become the leading edge of a new aerospace revolution.

PM





COMMUNICATIONS

'Hi' in the sky

The communications network for NASA's space station in the 1990s will be like a

TV network, air traffic control, metropolitan telephone exchange and large computer installation all in one. Designed by Harris Corp., the 300-mile-high network will provide more than 60 com-

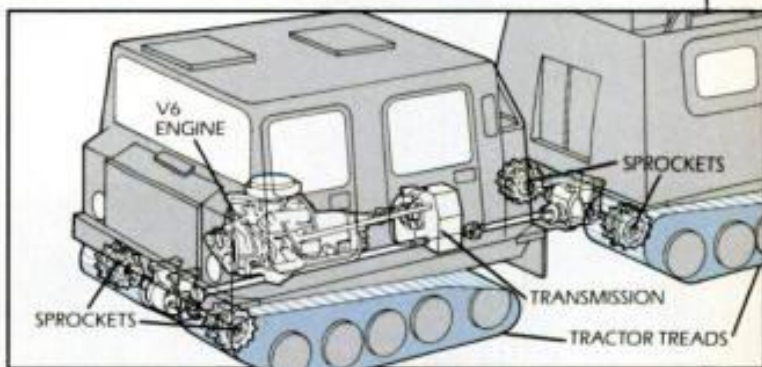
munications links, using 30 antennas. It'll keep in touch with satellites, shuttles and NASA control centers on Earth. Communication with ground will allow scientists on Earth to observe and in-

teract with experiments in space. Expected to last 30 years, this space network will provide improvements in Earth communications and new devices to lower technology costs.

TRANSPORTATION

Hauling it everywhere

The Bearcat from Hagg-lunds AB in Sweden is the newest concept for transport or rescue in any terrain. Its greater mobility derives from all four rubber treads being powered by a V6 gas engine or optional turbodie-



sel. A unique gearing system allows one engine to power all treads and still pivot or articulate. With options for cranes, truck beds and fire

pumps, the Bearcat can do almost anything. In snow, ice or mud, and fully amphibious for swamp or river, it can go anywhere. **TU**

ENGLAND'S FRENCH CONNECTION



English Channel
digging machines
will bore through
chalk, remove it by
conveyor and install
the tunnel walls.

The equipment is ready and digging starts soon on the tunnel that will connect England and France.

BY FRANK P. DAVIDSON

The juggernaut moves along ponderously, chewing out the inside of the White Cliffs of Dover and spitting chunks of rock into a conveyor behind it. The machine is huge, but the most impressive part is a simple device in the nose end, a 15-yard-dia. hydraulic razor with dozens of modular ceramic teeth that nibble at the chalk beneath the English Channel. Some 40 years ago, this scene was a dream shared by myself and a handful of men interested in macro engineering—the creation of huge public works projects. But now that dream is a reality. The long-awaited English Channel Tunnel will soon be under construction. The 30-mile tunnel, slated for completion within nine years, has a projected price tag of \$3 billion or more, depending on inflation. You may have in your mind's eye the image of a tunnel filled with autos, buses and trucks.

Frank P. Davidson is program coordinator of the Macro Engineering Research Group at the Massachusetts Institute of Technology and author of *MACRO: A Clear Vision Of How Science And Technology Will Shape Our Future*.

PM ILLUSTRATION BY JIM DINEEN



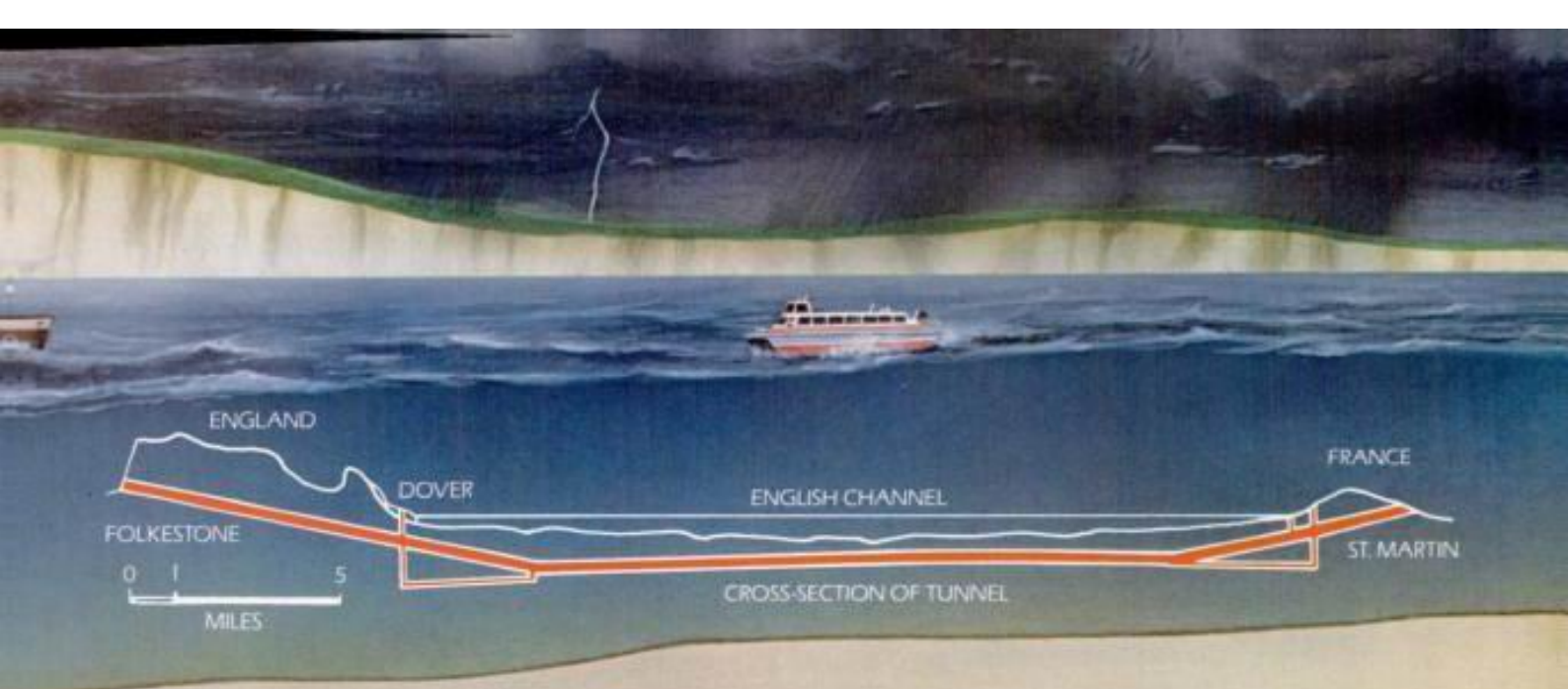
but the designers have opted for something swifter—a 3-tube tunnel that I call the Channel Subway. The center tube will serve as a service tunnel with crossovers to either side spaced some 400 yards apart. The two outer tunnels will carry rails for trains running in opposite directions.

Trains clattering through the tunnel at high speeds will carry motor vehicles piggyback on railroad cars. Passengers sitting in the forward part of the train will load and unload their vehicles at terminals in Calais, France, and Dover, England.

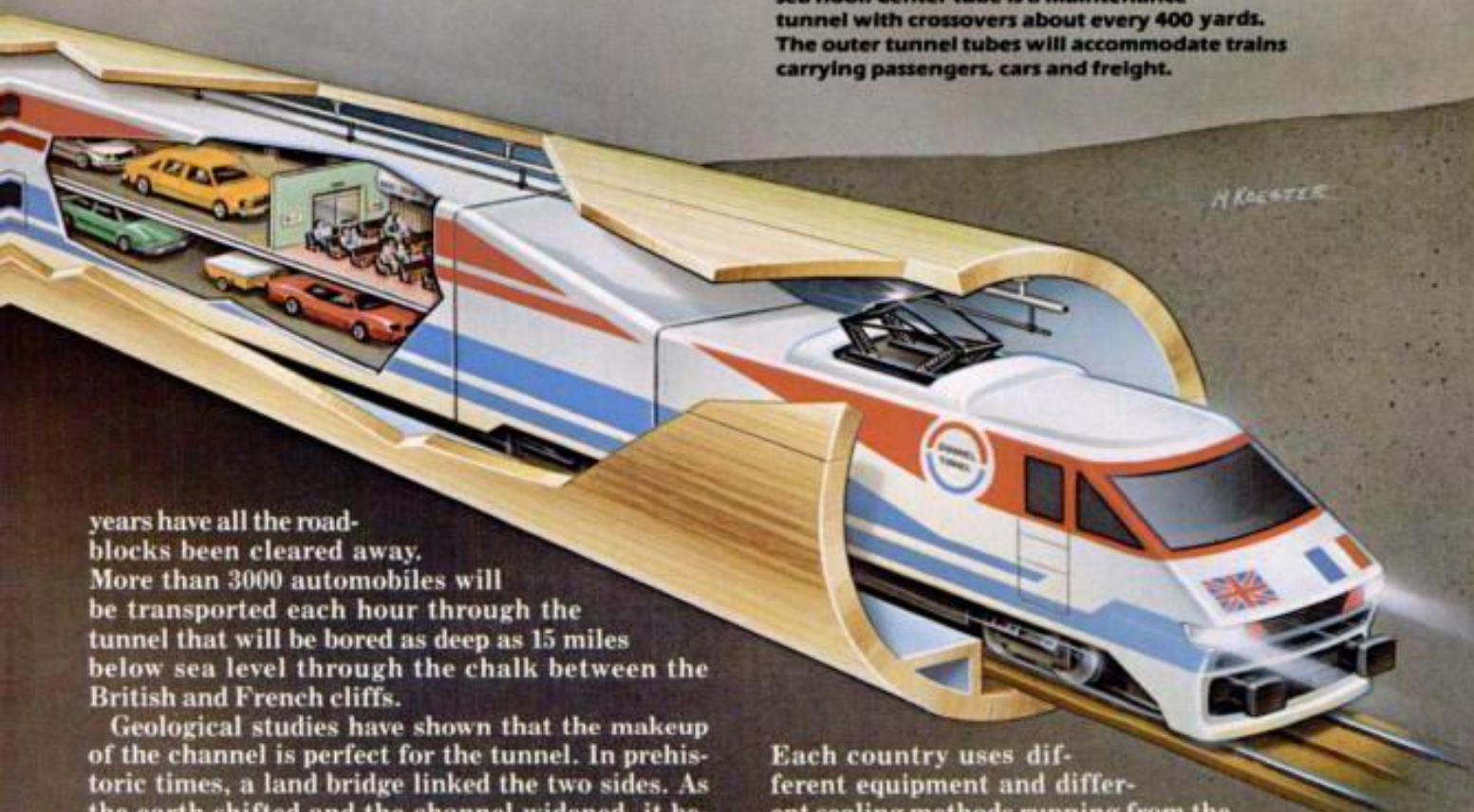
The spectacular “Chunnel” will allow travelers to go from London to Paris in 4½ hours, about the same time it takes to fly, including trips to and from the airports. Only now, the travelers won’t care about the frequent drizzle and fog that grounds commercial aircraft. Later, when France’s high-speed rail system is extended all the way to London, the trip will take 3½ hours.

Europe has long considered the value of an English Channel tunnel, but only in the last couple of

PM ILLUSTRATION BY MICHAEL KOESTER



Three tubes will run beneath the sea floor. Center tube is a maintenance tunnel with crossovers about every 400 yards. The outer tunnel tubes will accommodate trains carrying passengers, cars and freight.



years have all the road-blocks been cleared away. More than 3000 automobiles will be transported each hour through the tunnel that will be bored as deep as 15 miles below sea level through the chalk between the British and French cliffs.

Geological studies have shown that the makeup of the channel is perfect for the tunnel. In prehistoric times, a land bridge linked the two sides. As the earth shifted and the channel widened, it became submerged. The result is a channel floor of continuous chalk from England to France. The porous material is relatively easy to cut and remove as construction progresses.

The construction methods will be nothing short of ingenious. Trial tunnels were excavated from 1973 through 1975 on the British and French sides.

Each country uses different equipment and different sealing methods running from the opposite ends, but the end result is designed to meet at the channel's midpoint beneath the chalk floor.

The British trial tunnel was dug with a special machine built by the Robert L. Priestly Co. Its head cuts at a top speed of $4\frac{1}{2}$ rotations per minute and could be turned in either direction. Behind the

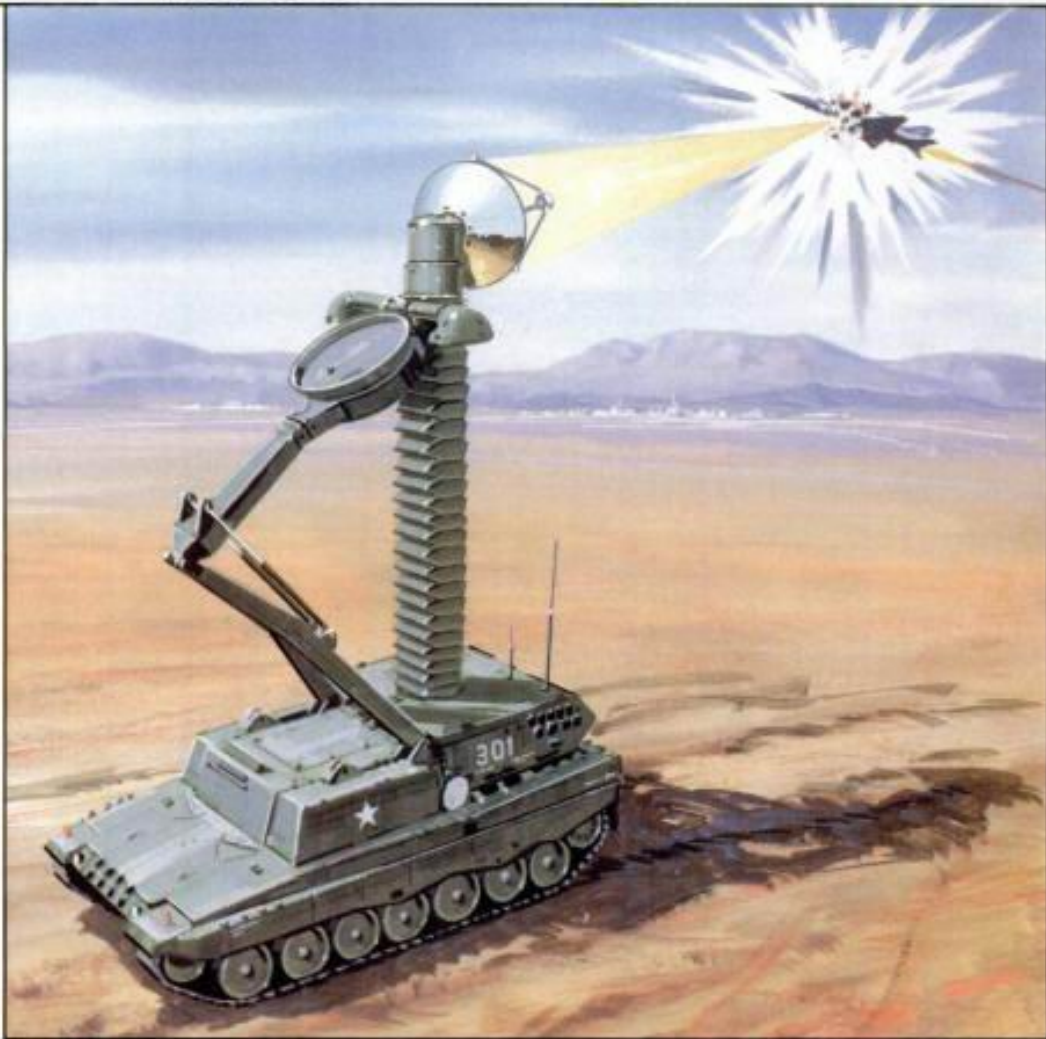
TECHNOLOGY UPDATE 10/86

MILITARY

NATO's tank is really light

Most talk about light tanks refers to the weight of the vehicle, but the latest weapon on the NATO drawing board is a tank that uses light as a weapon. Under development by a West German consortium, the proposed tank (right) carries a high-energy laser (HEL) mounted on an accordion tower that stows in a 2-man Leopard Tank.

The HEL tank's design is mostly for anti-aircraft or missile defense. The laser source is a gas dynamic laser, the most powerful gas laser. Right now, prototypes are being developed in Germany, with the United States theoretically out of the picture. But the Defense Advanced Research Projects Agency last year abandoned a similar project, and it is expected that the German tank will be tested in the U.S. If it works, America probably will buy it rather than build it.



Play it again, Sam

Air strikes in Israel have proven that surface-to-air (SAM) missile sites are vulnerable to attack. And the American raid on Libya underscored the ease with which a high-tech jet can destroy a SAM installation. But the British Army has come up with a SAM missile

rig that moves as quickly as a soldier can hit the dirt. The "man-portable" SAM, whose guidance system is still secret, has been designed with an extra stinger: It's made to knock out tanks. The rig (left) uses a 2-man crew, one firing and the other sitting. Shells reportedly will move at Mach 5, so fast that no warhead is needed to make these stingers deadly.

Tomahawk is on target

The missile below has just traveled 500 miles down-

range at altitudes as low as 500 ft. It's a Tomahawk Cruise Missile, the newest weapon in the American arsenal, and the Defense De-

partment gives it high marks for accuracy and maneuverability. The missile is able to change course even when it's within a few feet of the tar-

get. That helps it strike with uncanny accuracy after evading enemy radar. The Navy fired the missile from a cruiser in the Gulf of Mexico.



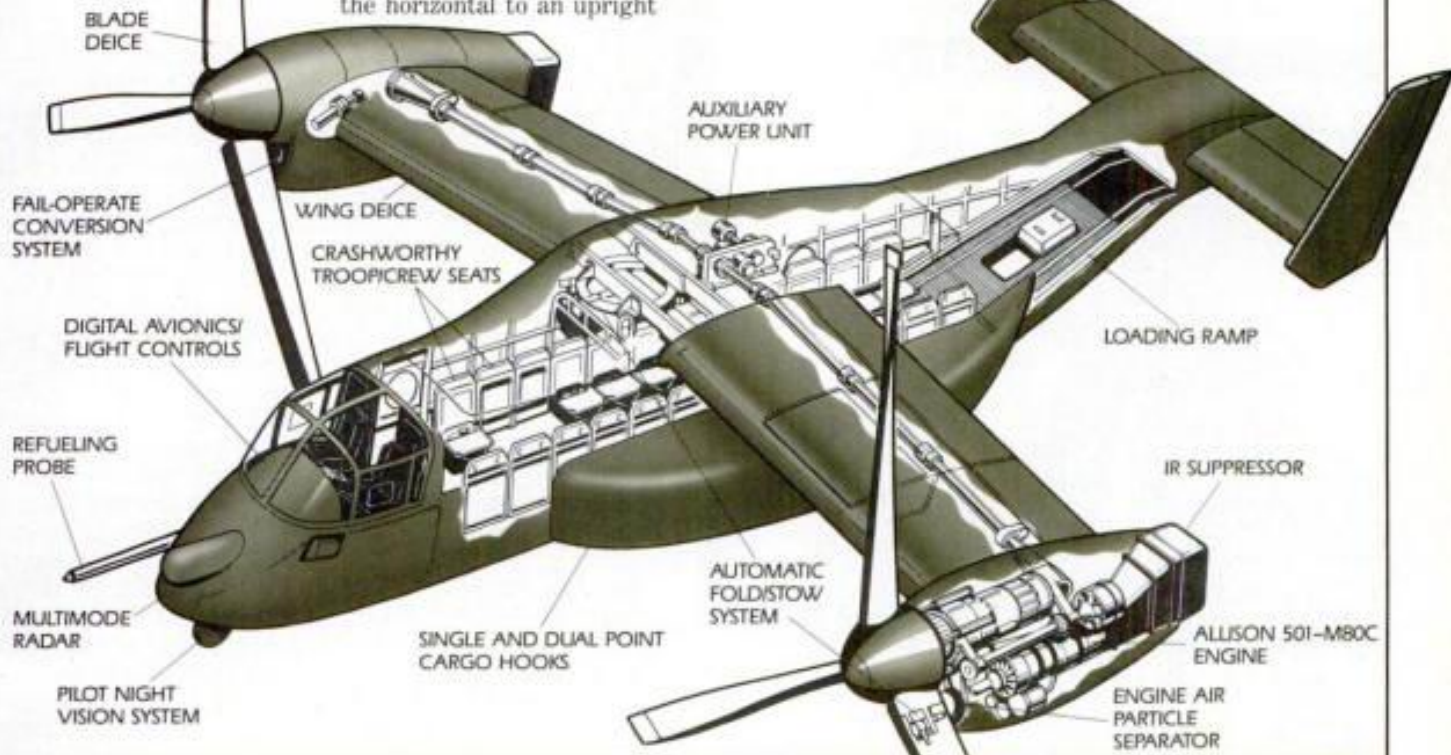
AVIATION

Tilt rotor taking off

Boeing and Bell Helicopter are teaming up to produce the first six prototypes of the V-22A Osprey. The twin propellers can be tilted from the horizontal to an upright

position so the plane flies like a helicopter, with very short takeoff and landing capabilities. The Osprey, which goes to flight testing next year, will be equipped with high-tech avionics and other leading-edge systems

shown in the illustration below. The Navy is expected to be the first customer.



Soviet jet escort service

The growing Soviet Union air arsenal now includes an updated version of the SU-27 Flanker.

Packing air-to-air missiles, this Mach 1 jet (above) has been seen in the Middle East, flying off the decks of Soviet aircraft carriers in support of longer-range fighter-bombers.

Jane's Defence Weekly,

the authoritative British military journal, says the jet's fuel supply has been cut down to make more room for weaponry. That underscores the jet's mission of getting Soviet attack craft into action quickly.

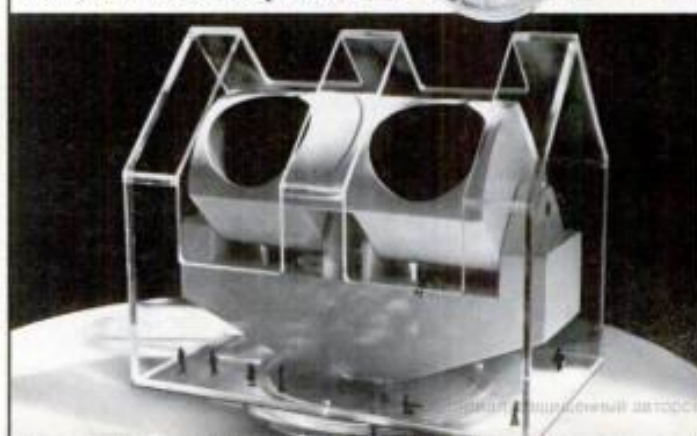
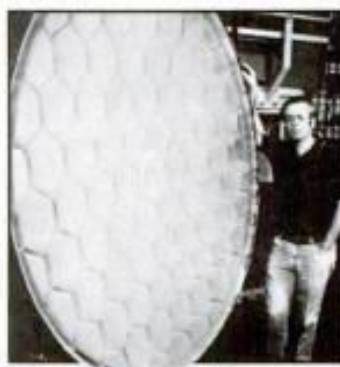
The SU-27 is supposed to defend departing squadrons against low-flying interceptor jets and air-to-air missiles. The jet also is being used for fleet defense.

ASTRONOMY

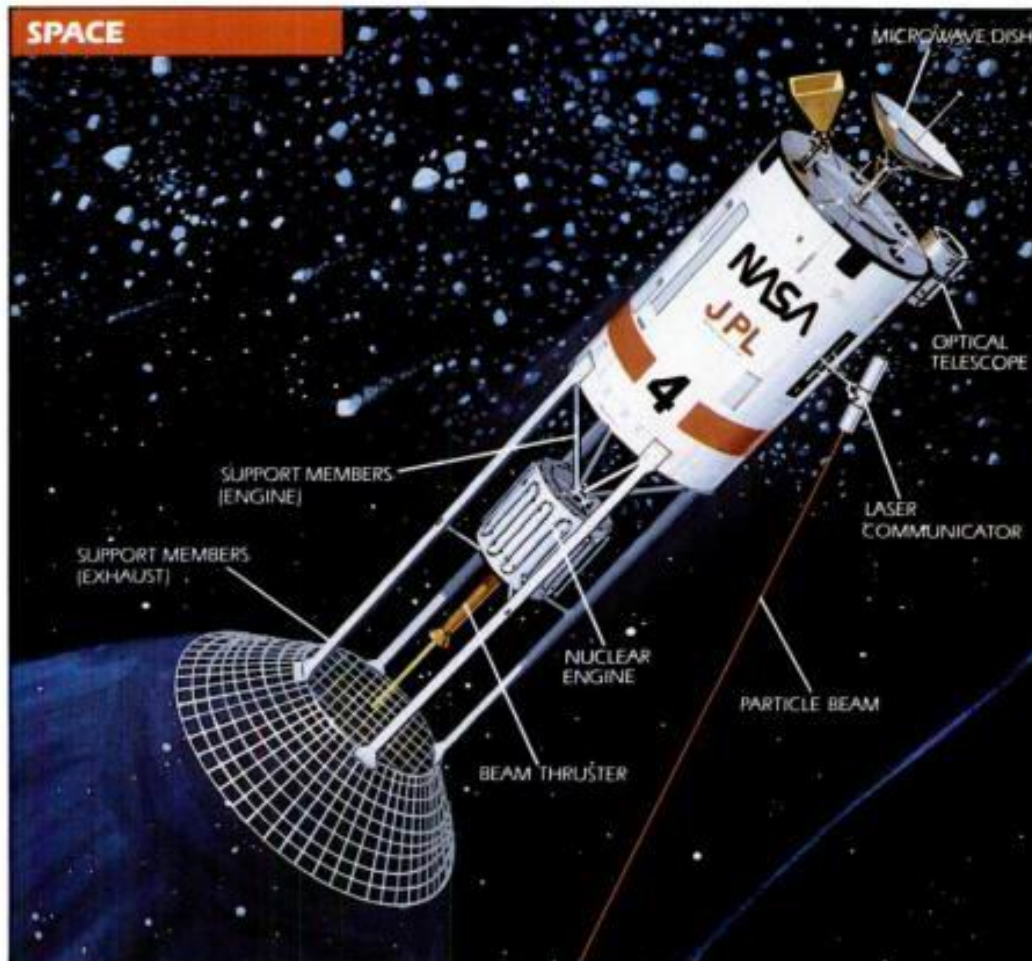
Not so distant stars

With the American space program grounded, astronomers are focusing more attention on the next super Earth-based telescope. The University of Arizona and Ohio State University are building a huge infrared telescope for Mount Graham in Arizona. Final design is still being worked out, but the leading contender is a 2-mirror stand with honeycomb,

315-in. mirrors. When done in the 1990s, it will be the Earth's most powerful telescope. **TU**



SPACE



Starship is a 2020 sureshot

Scientists at Jet Propulsion Laboratory have begun working on the design of the world's first starship. The ship is expected to be an elongated satellite with a nuclear engine that produces an ion beam of electrically excited atomic particles. The beam would be directed into a magnetically controlled thruster that sends a thin cloud of particles away from the ship, pushing it at speeds of more than 200,000 mph. NASA engineers believe the starship's first voyage could be to the Oort Cloud—the region where comets are formed, and the entryway to the universe beyond our solar system. Such a ship could be launched early in the next century for an Oort rendezvous around the year 2020.

WEATHER



Big system for small airports

Automated Weather Observation Systems (AWOS) are beginning to show up at small airports around the country where many or most pilots have instrument rat-

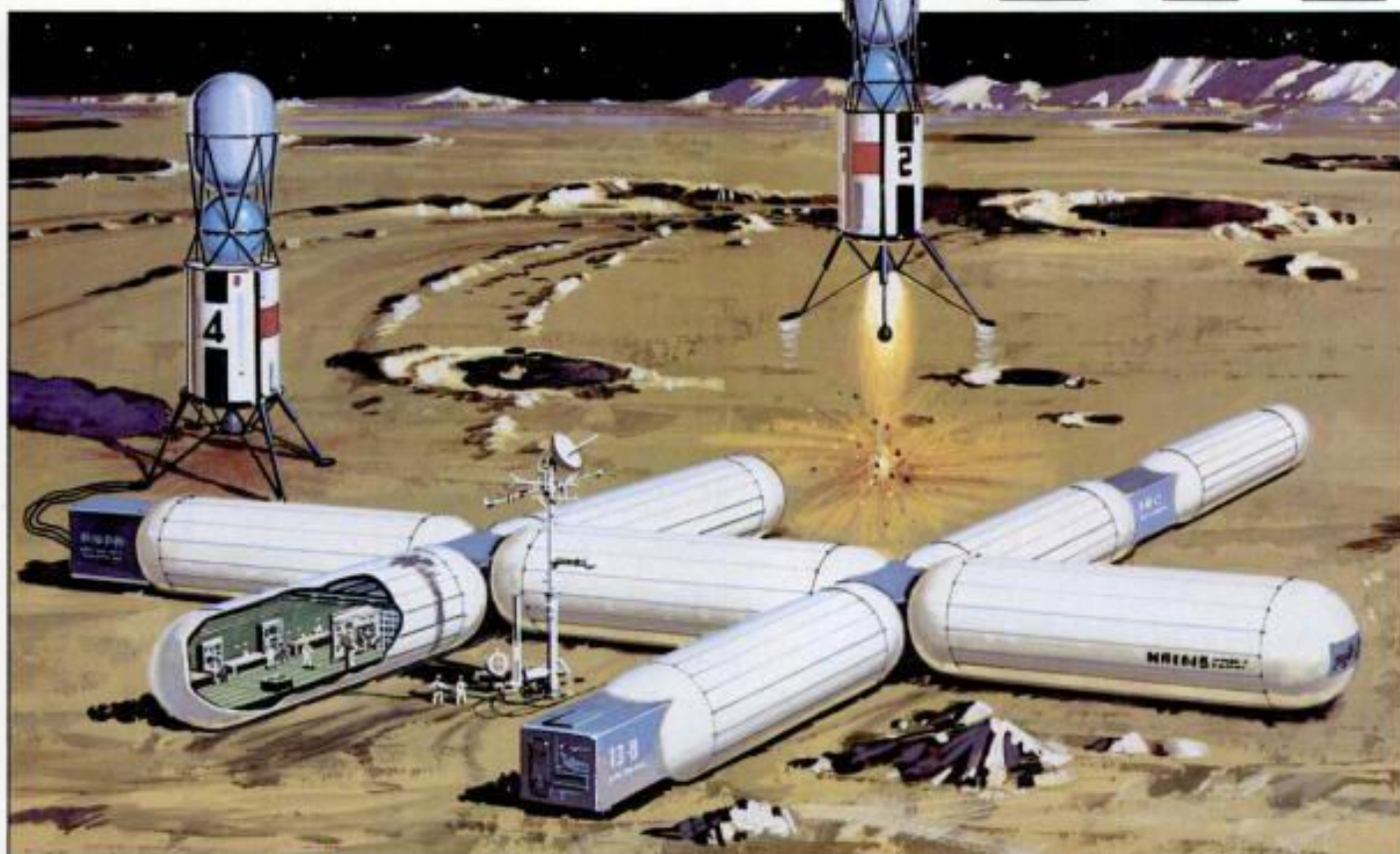
ings. The Handar AWOS-1, the first such system certified by the FAA, has been installed at Ada, Oklahoma. The system provides automatic weather updating every 60 seconds. It provides data on wind speed and direction, temperature, dew point, barometric pressure and time. The data can be picked up on a special cockpit radio frequency. The AWOS tower (left) includes an anemometer, wind vane, temperature and humidity sensors, surge suppressors for lightning, and a VHF antenna that transmits to pilots voice reports through a sophisticated voice-synthesizing system.

N-ROSS is supreme

Lockheed has released its concept art on the Navy Remote Ocean Sensing System (N-ROSS). The satellite would orbit Earth every 101 minutes, sweeping the globe below with a scatterometer to measure ocean-wave

heights, a microwave imager to measure wind speed and temperature, a microwave radiometer to map ocean currents, and an altimeter which would back up the scatterometer in determining ocean-wave characteristics. It would give extremely accurate weather reports as never before.





SPACE

A base for the moon

Scientists working on the Columbus Project at Lawrence Livermore Labs have come up with the basic design for a moon base that could be functioning by 1992.

The Space Station is expected to be operational at that time. The base would be serviced by lunar lander/return craft designed to deliver inflatable modules of the base.

Workshops, habitats and labs would operate inside the modules. Oxygen would be drawn from lunar rocks. The project is expected to cost \$250 million just to design.

ASTRONOMY

Star search starts anew

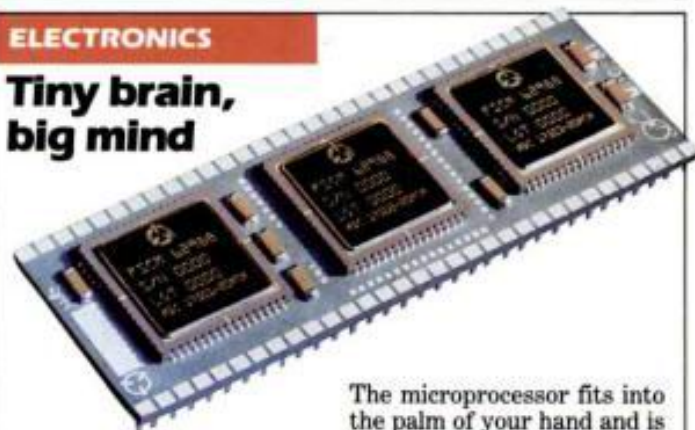
Cal Tech astronomers are in the first year of a 5-year project to photograph the entire northern sky using sensitive new photo techniques

resulting in a basic astronomical map. The Palomar Sky Survey will update a survey done in the 1950s when films were less sensitive. Astronomers can watch what the camera sees through new instruments (inset photo). Meanwhile, on Mona Kea, Hawaii, a multiuniversity consortium plans a similar southern search.



ELECTRONICS

Tiny brain, big mind



We're a step closer to the artificial-intelligence cockpit. McDonnell Douglas has built a powerful new microprocessor for F-18 jets. The processor allows the jet's computers to handle information 80 percent faster than in the past. The MDC281 has a 16-bit, integrated-circuit module specifically designed for the 21st century aircraft.

The microprocessor fits into the palm of your hand and is so good it eliminates eight other avionics data boxes used in early production models of the F-18. This is the memory that monitors fuel supplies, damage to the aircraft, air temperature and other important data. Avionics researchers are looking to a time when all the brains on a highly intelligent jet will take up less space than a personal computer.



HOT-AIR CHOPPER

The next-generation helicopter will fly without a tail rotor, gearbox or transmission. It will literally run on hot air.

BY FRED MACKERODT, Contributing Editor; Illustration by Jeff Mangiat

A helicopter lifts off from St. John's, Newfoundland, and heads out over the Labrador Sea. It's target: an oil rig 100 miles offshore. The chopper cruises steadily at 120 knots, but the ceiling is only 800 ft. and a freezing 50-knot wind whips the water. This is not helicopter weather.

About halfway into the flight, ice starts to form on the landing skids. But the pilot knows he and his seven passengers are safe. The main rotor will remain free of deadly ice because it's heated by 300° F compressed air moving through the core of the blades. The air is pushed by a single turbojet powerplant, and the craft is so quiet that the passengers hear only a muffled whine.

After about 45 minutes, the ice-encrusted oil-drilling platform moves into sight. Now over the bright red target on the pad below, the pilot applies

backpressure on the cyclic, or control stick, to arrest forward motion. At the same time, he eases the collective—a lever at his right side—to keep from ballooning higher. The craft goes into hover and the collective is lowered even farther, bringing the chopper down smoothly. The pilot applies right-rudder pressure to align the helicopter into the wind, then the craft touches down.

Such oil-rig flights would be among the most arduous assignments for this new helicopter being developed by Voljet International Corp. of Caldwell, New Jersey. The Voljet does away with the need for a tail rotor and a lot of other power-robbing and trouble-prone mechanical linkages found on conventional helicopters.

On conventional choppers, tail rotors primarily control the torque created by the engine twisting the



HOT AIR
FROM COMPRESSOR

HOLLOW ROTOR BLADES

HOT-AIR
OUTLET

The Voljet Air Pressure Jet copter would approach an arctic oil-drilling platform without concern about icing. This unconventional chopper has a turbine linked to a single-stage air compressor that blows hot air through the main rotor and out the rear of the chopper.

manjat

HOT-AIR CHOPPER

shaft which turns the main rotor. Without the tail rotor to keep things straight, the airframe would spin in the opposite direction of the main rotor.

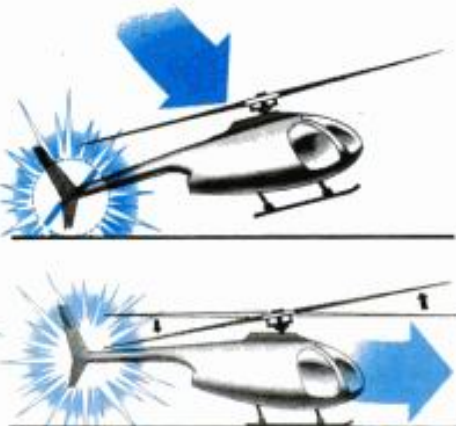
The Voljet 585 has a 1050-shaft-horsepower Pratt & Whitney PT6C-60 turbine—that much is conventional. It's hooked to a single-stage air compressor. Compressed air is ducted via the hollow rotor shaft and through hollow Kevlar-impregnated graphite rotor blades with a stainless-steel mesh in the leading edge. The air blows out the ends of the blades, spinning the rotor without creating torque.

Steering, which is also handled by the tail rotor in a conventional helicopter, is controlled by a simple rudder on the Voljet. During hovering and at speeds under 20 knots, the authority of this rudder is enhanced by directing the engine exhaust over it.

The Voljet, an Air Pressure Jet copter, is also much quieter than conventional choppers, a great advantage in an industry where operational noise considerations limit landing sights. A substantial portion of the noise in a conventional helicopter is created by tail-rotor buzz and transmission howl. Without these two items, the Voljet will be much quieter. In addition, the air exiting the wingtips smooths the airflow, diminishing another source of helicopter noise—blade slap.

The heat of the compressed air, which enters the rotor shaft at 300° and exits the blade tips at 200°, keeps the blades free of ice. This feature will be particularly important to offshore oil-rig operations where pilots are often forced to fly in icing conditions.

The lack of a tail boom adds to the maneuverability of the Voljet and is said to make it safer, especially in engine-out autorotation. Ninety percent of helicopter forced landings result in accidents involving the tail boom. There are two typical accident scenarios. In an effort to arrest the rate of sink without the benefit of power to "brake" for a landing, a pilot will tend to execute an exaggerated flare, making the helicopter rear back and driving the tail rotor into the ground. To avoid this, a pilot often attempts to make a flatter



Most accidents involving conventional helicopters take place on landing. At top, the pilot flares the craft and the tail boom strikes the ground. Above, chopper balloons forward to level off and the main rotor tilts back, cutting into the tail. Neither accident is possible with Voljet (below).



approach, sliding the helicopter in on its skids. This can cause the main rotor blades to tip, setting up a teeter-totter action which builds until it causes the main rotor to slice into the tail boom.

Because of the inertia built up in the freewheeling main rotor of the Voljet, the developers say that during autorotation it will be possible to make a soft landing, then take off, change position and land again—all without power!

Flying the new helicopter is also said to be much simpler, because it is inherently more stable and easier to control than a conventional chopper. According to the developers, "Anyone who can fly a Cessna 152 can fly the Voljet."

How does the general handling of a conventional chopper compare to the projected handling of the Voljet? In a conventional craft, collective (up-down) is raised to lift the helicopter off the

ground. At the same time, the throttle is increased to maintain both engine and rotor speed, and tail-rotor pedal (left-right) is applied to offset the resulting increase in torque to maintain the desired direction.

Cyclic (pitch forward-back, bank left-right) must now be applied to offset the lateral movement caused by the thrust of the tail rotor and the rolling tendency caused by the forces of the main rotor and tail rotor acting in different planes. The resulting tilt of the main rotor disc slightly decreases overall lift, requiring more inputs of collective, throttle and tail-rotor pedal.

Steady in the hover, a turn into the wind is initiated using the appropriate tail-rotor pedal. Throttle must be adjusted to compensate for the tail rotor's modified power demands, and collective must be adjusted to compensate for the resulting change in lift. Both throttle and collective requirements reverse themselves when the necessary tail-rotor pedal is applied to stop the hovering turn, when the craft is pointed into the wind.

To leave the hover and enter a normal climb, cyclic is eased forward, immediately causing reduced lift which must be compensated for by increasing collective. This necessitates increased throttle to maintain engine and rotor rpm. The resultant increase in torque must be offset by the application of the tail-rotor pedal to maintain the desired direction. Additional collective is applied to climb, again requiring throttle and pedal adjustments.

In the Voljet, collective is raised to leave the ground and stop at the desired hover height. The required rudder pedal is applied to position the nose into the wind. The cyclic is then eased forward, and the collective increased, establishing the desired climb.

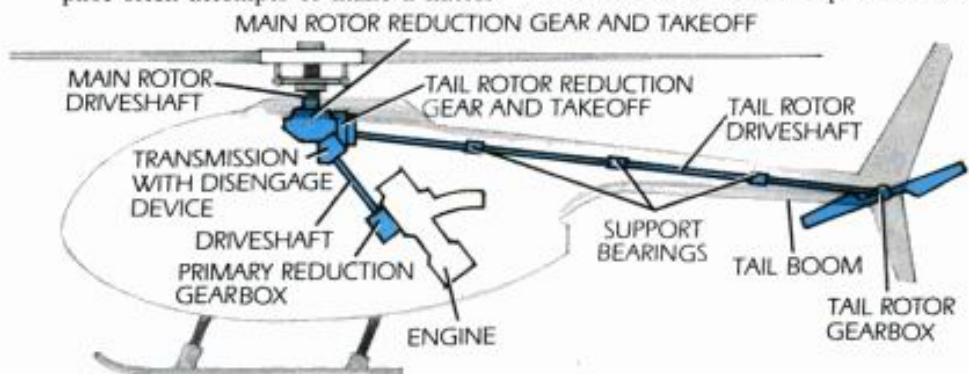
While the Air Pressure Jet helicopter is a thing of the future, the idea actually goes back to Galileo, whose sketches depicted an air-driven gyro craft. Work on APJ copters began 40 years ago.

What will make the system more viable today are the technological advances that have taken place in the past 30 years. Compressor efficiency, which was 30 percent in the '50s, is 80 percent today, aided by improved materials for tighter tolerances. Better seals allow more thrust to reach the blade tips, and rotor materials also have greatly improved.

Projected cruise of the Voljet is 120 knots with 52-gph fuel consumption. Eight people can be carried. The company, which has flown three proof-of-concept examples, plans to deliver the first \$480,000 Voljet in 1989.

POPULAR MECHANICS will fly a prototype sometime before the end of the year. Watch for our story.

PM



Color-coded parts in the conventional chopper shown above would not be in the Voljet.

MILITARY

Future Hawkeyes

The Navy currently places Grumman E-2C Hawkeye planes with radomes on aircraft carriers. The Hawkeyes can fly out of missile range and get a 360° view of the activities going on above and below the cloud decks. But there are a few things Hawkeyes can't do, and the Navy is shopping around for a next-generation "Multi-Mission Sensor System." Lockheed has shown us an early concept of two versions of the future Navy craft. One

is an Anti-Surface Warfare version (top in the illustration). The other is an airborne early-warning craft shown with the familiar radome. The future craft will be required to watch the skies for enemy aircraft and vessels, jam enemy radar, broadcast false radio messages and radar signals, and then some. In one configuration or the other, the new plane will drop mines at sea and carry out refueling missions for fighter planes. The planes are expected to have advanced aeronautical design, including winglets for lift and canards for greater maneuverability in flight.



Globe-trotting wings

Technology under development for America's stealth aircraft is being discussed as the wave of the future in moving air freight. Lockheed, under a grant from NASA Langley Research Center, is developing the initial design for a "global" transport plane. The technology being studied in laminar-flow experiments is the flying wing. Lockheed envi-

sions a stubby-bodied, rear-propfan-driven craft with winglets that could carry 150,000 pounds of cargo 6000 miles nonstop. The counter-rotating props could develop enough power to give the craft a mach 0.8 cruise speed. The wing design is the real key. Initial concepts call for a 227.2-ft. wingspan on a 125-ft.-long, 23.3-ft.-high body. NASA intends to test the wing concept on a C-141 test bed within the next two years.

Hard wheels, hard warfare

The first full-scale Small Intercontinental Ballistic-Missile Hard Mobile Launcher is undergoing tests. The 100-ft.-long, 200,000-pound vehi-

cle runs on a pair of 750-hp Cummins Diesel engines with all-wheel drive on 14 Goodyear military all-terrain steel radial tires. It will serve as a launcher for America's 30,000-pound single-warhead ICBM. The

small ICBM will have a range of 6000 miles when it undergoes test firing early in the next decade. The vehicle is being built by a consortium including Boeing Aerospace, Goodyear and Paccar Defense Systems. It must be

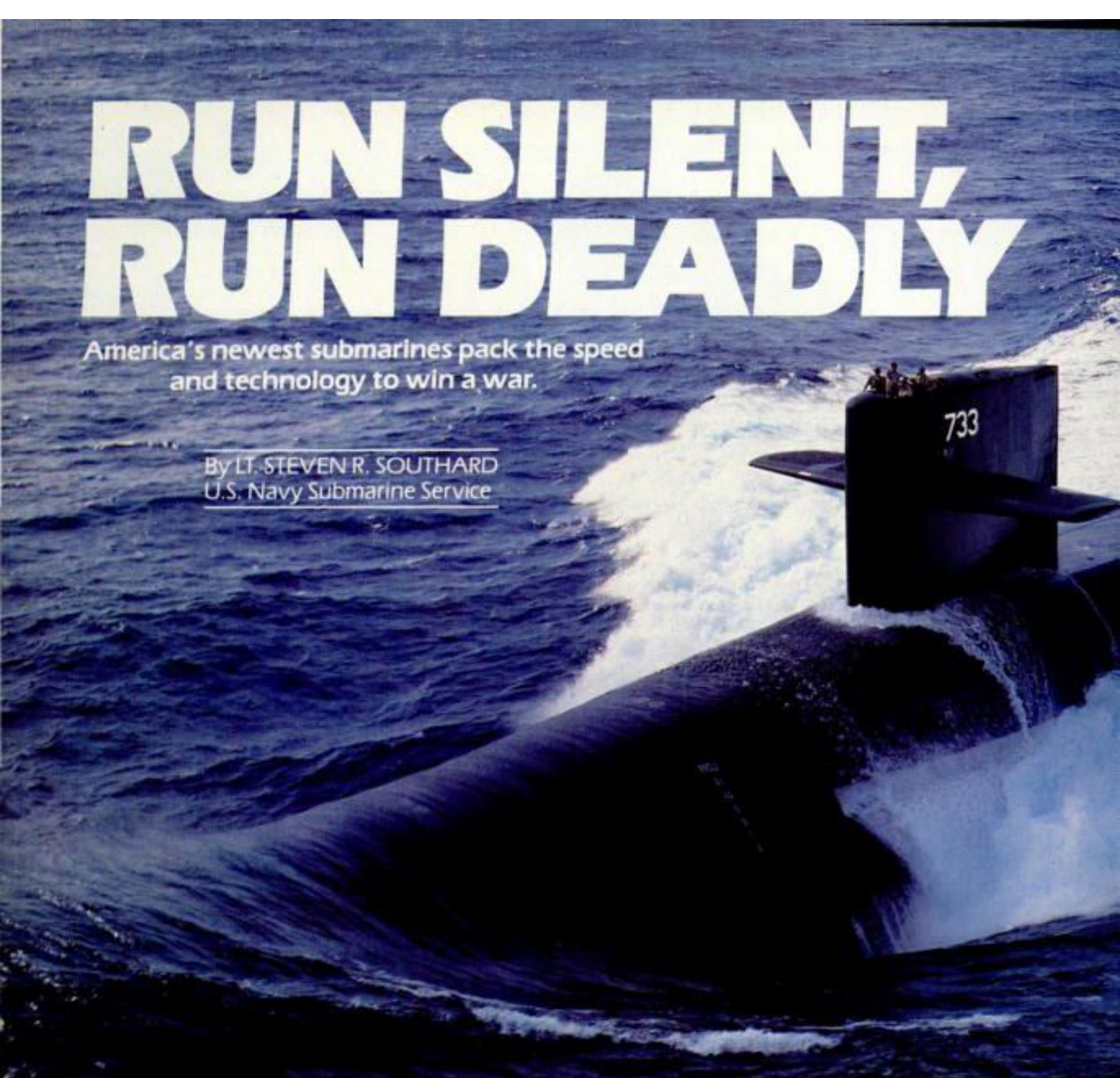
hard enough to withstand gamma-ray attack and fast enough to move out at 60 mph over rough terrain. In a crisis, the mobile launchers are supposed to disperse and await commands from a control center.



RUN SILENT, RUN DEADLY

America's newest submarines pack the speed
and technology to win a war.

By LT. STEVEN R. SOUTHARD
U.S. Navy Submarine Service



The fierce wind stirs up whitecaps on the restless ocean surface. Twenty-foot waves cascade into one another as the storm churns the water. Yet 150 ft. below, a giant black vessel glides, nearly oblivious to the seething tempest. The gentle rocking of the U.S. Navy's TRIDENT-class submarine is the only clue to the violence of the storm above. But the crew is not alone in this undersea world.

"Conn, Sonar, I hold a contact, a probable Soviet submarine, bearing two-five-eight." The sonar supervisor peers over the shoulders of the sonar operators at their console screens, vividly bright in the otherwise dark

sonar room. In the control room, the officer of the deck, or OOD, has ordered the crew to battle stations and informed the captain of the situation. The "old man" hurries from the wardroom, where he and other officers were enjoying a movie, to the control room.

There, he receives the reports from his battle station's fire control party:

"Contact now bears three-zero-two. He's drawing right."

"Contact classified as Soviet submarine, VICTOR III class."

"Ship manned for battle stations."

Acknowledging the reports, the captain mentally calculates the course, speed and range of the VICTOR, confirming the infor-



mation given him by his executive officer, or XO. In front of the XO are the operators of the Mark 118 Fire Control System. While the digital computers solve the complex geometrical problems of target position and necessary torpedo settings, other watchstanders are busy constructing paper plots of the action, both as a vital backup to the computers and for a permanent record.

"Right 15 degrees rudder, all ahead standard, make your depth 400 feet," the captain orders. Repeating and acknowledging the orders, the diving officer of the watch and the helmsman hasten to respond. The watch ensures that the helmsman and the planesman guide the 18,000-ton vessel swiftly yet

smoothly, with a precision of movement surprising for such a large ship.

An order to "Make torpedo tubes 1 and 2 ready in all respects" sets the anxious men in the torpedo room in motion, making their checks of torpedo conditions and ensuring that the tubes will fire when the switch in the control room is thrown. Just 250 ft. astern of the control room, highly trained engineering personnel operate the nuclear reactor and its associated steam plant, under the orders of the engineering officer of the watch.

"Match sonar bearings and shoot!" the captain orders. The torpedos run true. The TRIDENT has destroyed the enemy! This time, however, it is a training exercise, with

RUN SILENT, RUN DEADLY

a U.S. STURGEON-class submarine acting the part of the Soviet sub. The torpedos contain recording instruments instead of explosives and have been modified to turn away from the target.

Actually, ballistic-missile submarines like the TRIDENT usually *avoid* such confrontations in order to remain undetected. Even so, the realism of the exercise has demonstrated that if forced to attack in a real encounter, the TRIDENT would be victorious.

The most recent addition to the U.S. submarine fleet, the TRIDENT is also the largest and most heavily armed. The huge 4-deck vessel measures 560 ft. in length and 42 ft. in diameter. It weighs in at 16,600 standard tons. The \$1.5 billion TRIDENT submarine—also known as the OHIO class, after the lead ship launched in 1979—can dive deeper than 400 ft.

Cigar-shaped for high underwater speed, the smoothness of her hull is broken only by a small "sail"—the descendant of the World War II sub's conning tower—and the after control



Trident is steered in control room (above).
Topside, open hatches reveal missile silos.

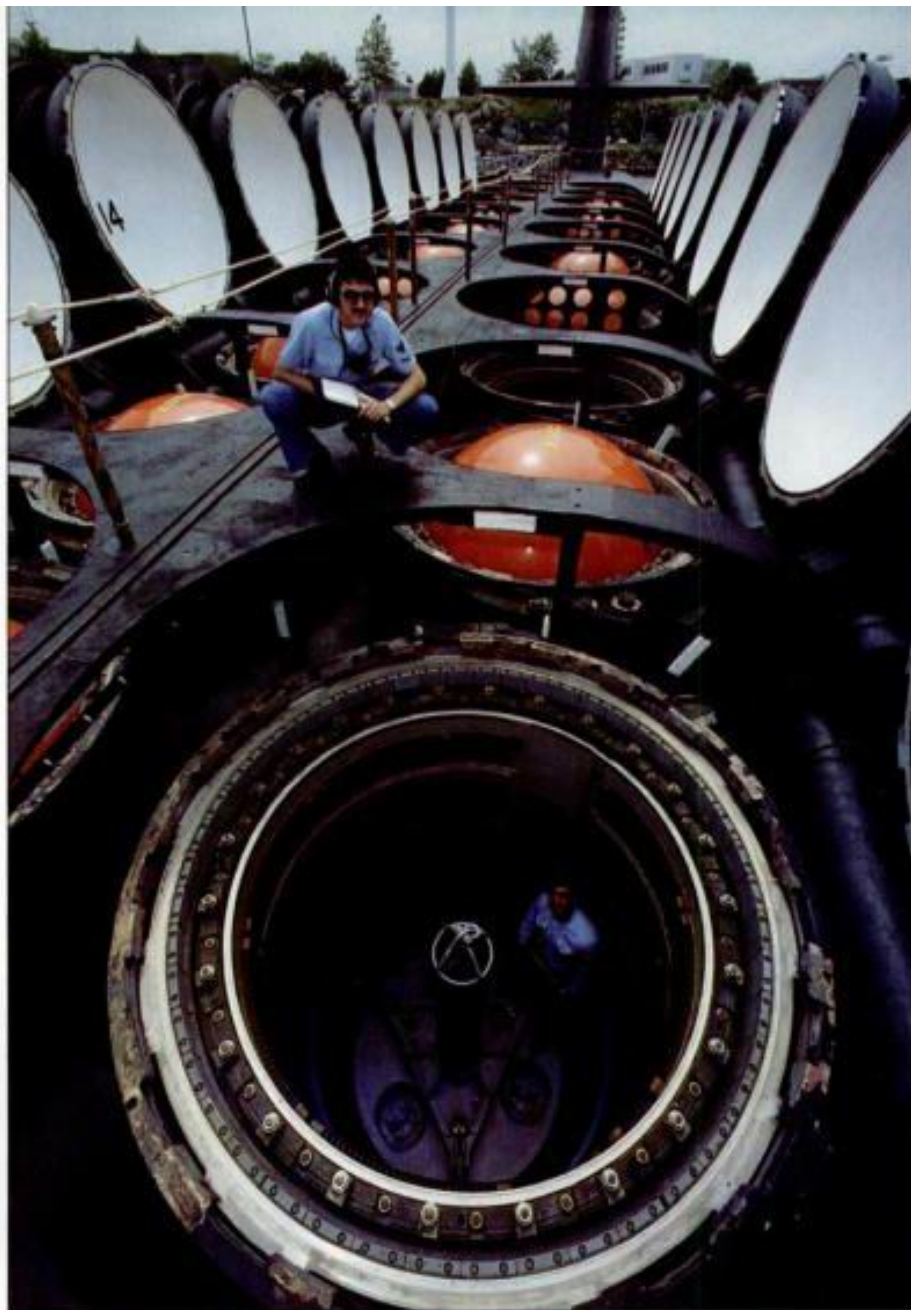
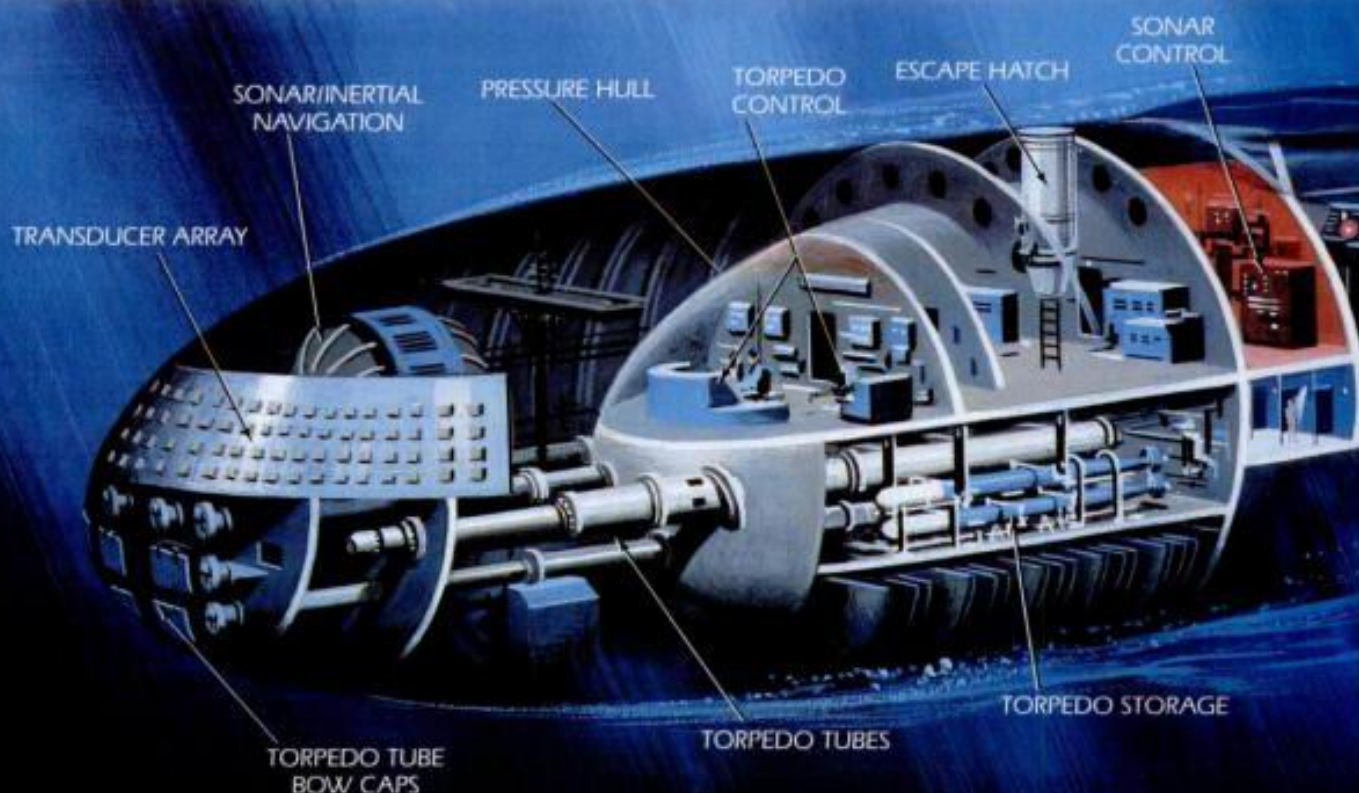


PHOTO BY BRIAN WOLFF



surfaces: the rudder and stern hydroplanes. The single screw aft is specially designed for quiet operation while providing a top speed of more than 20 knots. Driving that screw, and providing electric power for the machinery, is a General Electric S8G nuclear reactor.

The 24 Trident-I missiles, which represent a quantum leap in accuracy, range and warhead size over the earlier Polaris and Poseidon missiles, enable the submarine to fulfill its prime mission as a deterrent to nuclear war. In addition, she is armed with deadly Mk. 48 torpedos for active defense. To confound searching enemy ships and submarines, the TRIDENT is the quietest of U.S. subs, contains sensors to find hiding places, and can deploy acoustic decoys to deceive enemy sonars.

Because of their construction, the interior spaces of underwater vessels tend to be more cramped than surface ships. However, the TRIDENT's dual "Blue" and "Gold" crews, each with 15 officers and 150 enlisted men, have more living space and better accommodations than those aboard any other U.S. submarine. Roomy 9-man berthing areas are nestled between the mis-



Soviet Victor II subs pass in rare review photo shot during a Baltic Sea operation.

PHOTO BY TASS FROM SOVFOTO

sile tubes. Entertainment facilities include a videotape player, stereo system, jukebox, gym with body-building equipment, Ping-Pong table, ice-cream machine and library. The heads even contain porcelain toilets with 1-valve operation, a true luxury on a submarine. The increased emphasis on crew comfort is important during the TRIDENT's 70-day patrols.

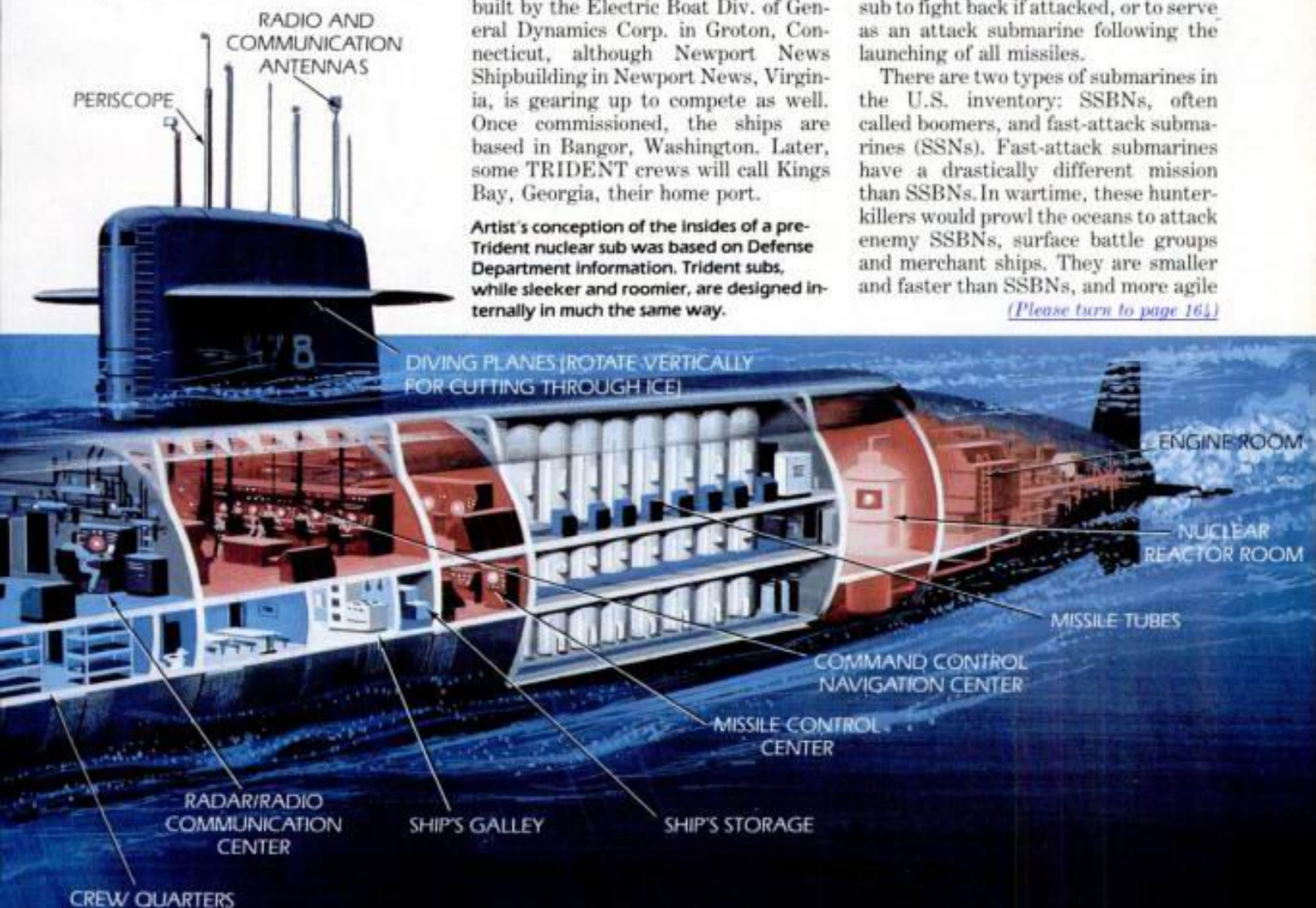
The commissioning of the USS Nevada in August 1986 brings the total number of OHIO-class subs to eight. At present, all TRIDENT subs are being built by the Electric Boat Div. of General Dynamics Corp. in Groton, Connecticut, although Newport News Shipbuilding in Newport News, Virginia, is gearing up to compete as well. Once commissioned, the ships are based in Bangor, Washington. Later, some TRIDENT crews will call Kings Bay, Georgia, their home port.

Artist's conception of the insides of a pre-Trident nuclear sub was based on Defense Department information. Trident subs, while sleeker and roomier, are designed internally in much the same way.

To accomplish its mission, a fleet ballistic missile submarine (SSBN) must employ long-range missiles, resulting in a patrol area large enough to hide in, and close enough to home port to minimize transit time. The ship must have a highly accurate navigation system, since the targeting of the missiles depends on the firing platform's knowledge of where it is. The SSBN must be very quiet, to remain undetected in an environment where sound can travel for great distances. Sufficient torpedos must be carried aboard to enable the sub to fight back if attacked, or to serve as an attack submarine following the launching of all missiles.

There are two types of submarines in the U.S. inventory: SSBNs, often called boomers, and fast-attack submarines (SSNs). Fast-attack submarines have a drastically different mission than SSBNs. In wartime, these hunter-killers would prowl the oceans to attack enemy SSBNs, surface battle groups and merchant ships. They are smaller and faster than SSBNs, and more agile

(Please turn to page 164)



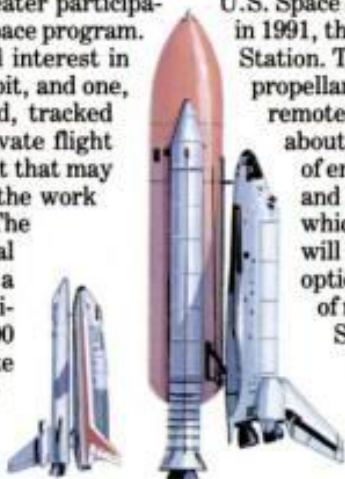
PM ILLUSTRATION BY DEAN ELLIS

PM TECHNOLOGY UPDATE 5/87



Private Shuttle May Fly In The 1990s

President Reagan last year called for greater participation by the private sector in the future space program. Several companies already have announced interest in the launching of satellites into low Earth orbit, and one, Space Industries, has successfully launched, tracked and recovered a Conestoga rocket on a private flight from Texas down the Gulf missile range. But that may turn out to be small potatoes compared to the work planned by Third Millennium of Nevada. The company, which uses the Roman numeral MMI (2001) as its logo, is currently building a prototype Space Van, a fully reusable mini-shuttle with a payload of more than 6000 pounds to low Earth orbit. That would make it capable of delivering supplies to the planned Space Tugs of NASA for delivery to the Space Station in the 1990s. The Space Van also is designed to deliver satellites into low orbit. The Space Van will be just under one half the length of the



The Third Millennium Space Van, left, shown in scale with the Shuttle.

U.S. Space Shuttle and is expected to be ready for service in 1991, the year before construction starts on the Space Station. The Van would be launched on a reusable liquid-propellant booster, which would have wings and be remotely guided to a recovery site after separation at about 15 miles above Earth. It will also carry a set of engines in its rear to give it both orbital transfer and fly-down capabilities. Unlike the Shuttle, which returns to Earth as a glider, the Space Van will be able to rely on its engines for more landing options, and for a higher, and thus a cooler, angle of re-entry. The Van will not need weight-adding Shuttle-type ceramic tiles for heat deflection. The rear engines are expected to be eight Pratt & Whitney RL10 rockets. The Space Van can be flown by a crew of three.

Editor: Dennis Eskow
Contributors: Michael Fillon, Jack Hammond,
Steve Eskow, Ted Francis, Richard Schrader

TECHNOLOGY UPDATE

AVIATION

Cargo flies first class

McDonnell Douglas has produced a concept for a new version of the ultrahigh-tech MD-11. The Combi will fly passengers and extra cargo on the same



deck. A typical arrangement, shown in illustration, would provide room for 214 passengers forward and six

freight pallets aft. The MD-11 itself is being offered in two fuselage lengths, one 18.6 ft. longer than a DC-10 and the other the same length as the popular jumbo jet. All the new MD-11s carry

three powerplants, either the General Electric CF-6 or the Pratt & Whitney 4000. Additional winglets on the MD-11 wingtips and other advances in the airfoil design give the

MD-11 about 17 percent greater fuel efficiency than the DC-10. All computerized systems are redundant with major systems on mechanical backup. The cockpit is entirely computerized.

MEDICINE

Brace yourselves

The knee brace has become a common piece of medical equipment that allows sports enthusiasts and professionals to get back into the game quickly after a knee injury. The best of today's knee braces, like the Lenox Hill model, are using a lot of composite materials to keep the



weight low and the flexibility high. But a new brace

developed by Georgia Tech engineer Ray Vito and his

associates is made entirely of composites, and, depending on the configuration for a particular athlete, can weigh one-quarter to one-third less than the best of the existing knee braces. The Georgia brace is comprised of a set of rigid components which can be shaped in a variety of ways. Because of the composites, the brace can stretch to accommodate younger wearers who are still growing.

AUTOMOTIVE

Stick in the mud

A British firm, Power-House, has developed a rescue device for vehicles mired in mud or snow. It fits on a flatbed truck and is rolled to a stuck vehicle under the power of a small motor. A pallet rolls back from the rescue device and hydraulic jacks push up the front end of the stuck vehicle enough to get the pallet under the wheels. After the stuck vehicle is secured, its driving wheels turn the treads.



This looked like an event history was going to treat kindly. Wally Schirra was on my left and Frank Christensen, the ultimate aviation entrepreneur, was on my right. Burt Rutan was busy bantering with jet jockey J.P. Tristani and **POPULAR MECHANICS'** own Fred Mackerodt was tossing in his 2 cents.

Guys like these don't spend a lot of time sitting around with their feet up unless there's a really good reason. And here they were, sequestered in Rutan's conference room at his Scaled Composites, Inc., skunk works in California's high desert country outside Mojave. None of them would stand in line for \$100 bills, but they had dropped everything and journeyed from all parts of the country because they felt the subject was important. They had come to spend a complete day pooling their knowledge and experience to design an airplane. Not just any airplane, but the Piper *Cub* for the next dozen generations.

Designing the *Cub's* replacement in a single day is a mighty tall order. For one thing, since 1936 the Piper J-3 has been the standard by which all other trainer and entry-level airplanes have been judged. That's an amazing fact when you remember the *Cub* represents the ultimate in low-tech engineering. But for people who yearned to fly, the *Cub* made it possible—forming a connection between thou-

sands of pilots and the exhilaration of flight.

The luminaries gathered at Mojave had come to do more than simply design an airplane. They had come because aviation is ailing, and a new-generation *Cub* would be part of the cure. The number of student starts has declined steadily, not to mention the number of new pilots who buy small airplanes. Certainly, one of the contributing factors is the appalling increase in the cost of flight instruction and training aircraft.

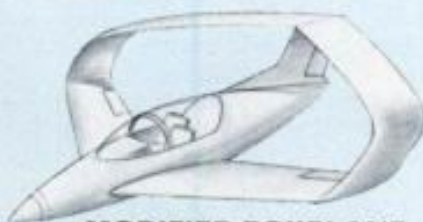
The cause for the increase is a complex interplay of inflation, labor, FAA certification costs and, most of all, product liability insurance. Product liability has had such a damaging effect on aviation that the Mojave Pow Wow decided it was best to ignore the regulatory problems of liability and FAA certification and



TAIL-MOUNTED ENGINE



BIPLANE



MODIFIED BOXPLANE



JOINED WING

Several revolutionary concepts for the light plane of the future evolved from PM's aviation think tank. Among them (top left) was a plan for mounting the engine in the tail; a contemporary biplane (top right);

a NASA inspired boxplane (bottom left); and a radical joined wing (bottom right). The final aircraft (illustration) was a synthesis of ideas drawn from the leading edge of contemporary aviation technology.

WINGS FOR TOMORROW

Burt Rutan and a panel of aviation experts help PM design an affordable entry-level sportplane for the 21st century.

BY BUDD DAVISSON; Illustrations by Mark McCandlish



do its design work in a vacuum.

When tackling the project, PM selected the following team and turned it loose: Burt Rutan, world reknown designer of a wide variety of airplanes, including the *Starship* and *Voyager*; Wally Schirra, Navy test pilot and the only astronaut to hitch rides in all three of America's early space vehicles—Mercury, Gemini and Apollo; Frank Christensen, industrialist/entrepreneur who owns the factory that cranks out Christen Eagles, Pitt Specials and soon the Husky bushplane; Fred Mackerodt, aviation journalist and experienced pilot; J.P. Tristani, commercial airline captain and former Navy test pilot; and Mark McCandlish, one of this country's foremost aviation illustrators. Rounding out the list were PM's Editor-in-Chief Joe Oldham and Science/Technology/Aerospace Editor Tim Cole. I was there to serve as referee.

As we finished breakfast around the conference table, we laid down our only two hard and fast guide-

lines: First, the airplane was supposed to be of revolutionary design. Anything less, we felt, would fail to breathe life into aviation. Revolutionary versus evolutionary... we soon had to chant it to ourselves to keep on the right track.

The second guideline was really a definition of the mission. The airplane was to be an entry-level training platform that removed all hardware barriers between flight and the average man on the street. It was to be the most user-friendly airplane ever designed.

"Revolutionary versus evolutionary" was a bigger challenge than most of us anticipated. We sailed right through the second subject of discussion—the number of seats. Two was the unanimous answer. Then, I posed the question of whether the seats would be tandem or side-by-side. The military types preferred tandem. As an instructor, I pushed for side-by-side.

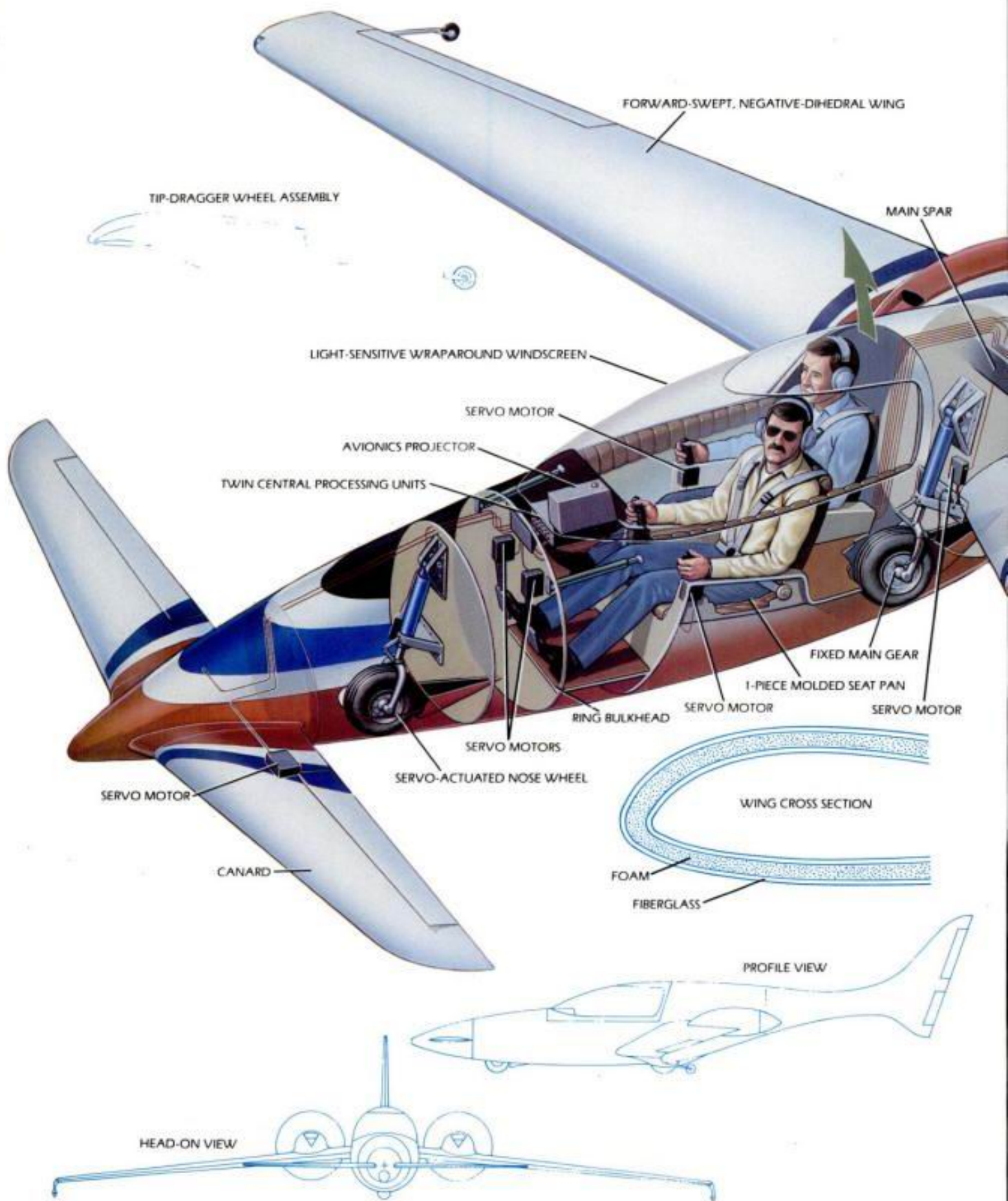
Then Burt spoke.

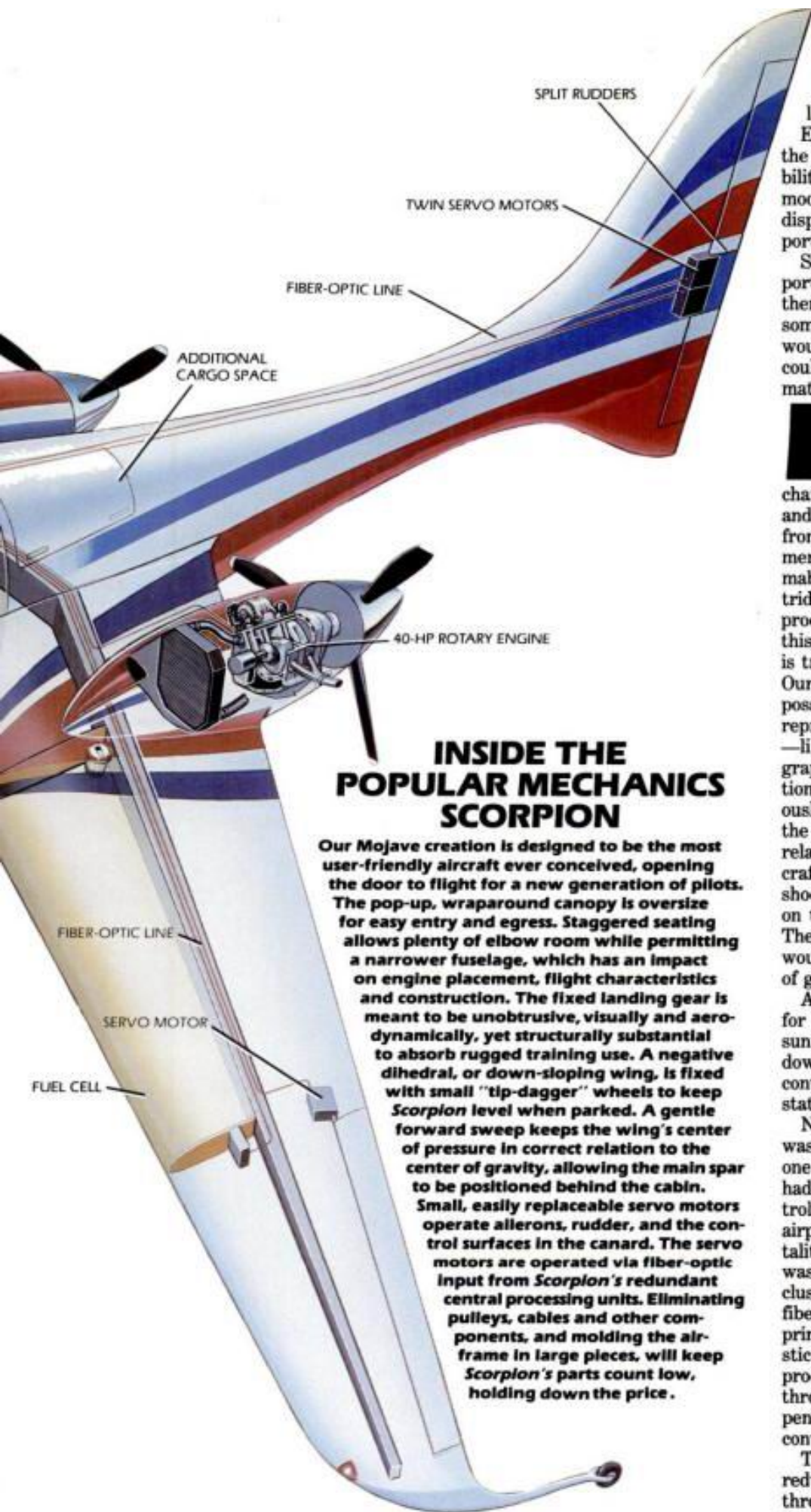
"Why does it have to be either?"

It was like throwing on a light

switch. Burt made the case for staggering the seating—setting the right seat back approximately 15 in. and overlapping the left seat by about 6 in. This gave a bundle of benefits: narrower fuselage, the instructor could still read the student's face for signs of panic, the instructor was closer to the student's line of sight so their visual references were almost the same, and the right seat passenger/instructor had unrestricted access to the small payload bay behind the pilot. Most important, staggering the seating gave passenger and pilot plenty of elbow room—a pretty dear commodity on a lot of 2-place airplanes with athwartship seating.

The PM *Scorpion* was taking shape from the inside out. The seating discussion led to flight controls and from there to the instrument panel. Everybody in the room agreed that a side stick on an armrest at the side of the seat was the best way to control the airplane. At the same time, it was argued that the left seat—the command/student seat





INSIDE THE POPULAR MECHANICS SCORPION

Our Mojave creation is designed to be the most user-friendly aircraft ever conceived, opening the door to flight for a new generation of pilots. The pop-up, wraparound canopy is oversize for easy entry and egress. Staggered seating allows plenty of elbow room while permitting a narrower fuselage, which has an impact on engine placement, flight characteristics and construction. The fixed landing gear is meant to be unobtrusive, visually and aerodynamically, yet structurally substantial to absorb rugged training use. A negative dihedral, or down-sloping wing, is fixed with small "tip-dagger" wheels to keep Scorpion level when parked. A gentle forward sweep keeps the wing's center of pressure in correct relation to the center of gravity, allowing the main spar to be positioned behind the cabin. Small, easily replaceable servo motors operate ailerons, rudder, and the control surfaces in the canard. The servo motors are operated via fiber-optic input from Scorpion's redundant central processing units. Eliminating pulleys, cables and other components, and molding the airframe in large pieces, will keep Scorpion's parts count low, holding down the price.

to identify his destination airport, and let the digital railroad track lead him there. No muss. No fuss. Existing loran units already allow the pilot this kind of navigational flexibility as well as having various backup modes such as a single button that displays the location of the closest airport.

Some also display runway and airport information. In short, getting there by airplane has already taken some fabulous strides. The Mojave bird would integrate existing systems that could simplify all phases of flight information and control.

In addition, some loran units currently evolving in the marine community merge position with environmental information like channel markings, depth, obstructions, and so on. This information is digitized from charts prepared by the government and installed on small programmable read-only memory (PROM) cartridges that plug into a loran's central processing unit. It won't be long before this kind of technology (technology that is truly inexpensive) reaches aviation. Our group concluded that it will soon be possible to project a visual digitized representation of ground features—like airport runways, towns, topography, TV towers and other obstructions—using simple icons. A continuously updated loran position would shift the unfolding scene on the windscreen relative to the movement of the aircraft, allowing the pilot to visually shoot approaches in any weather based on the image on his own windscreen. The flight envelope railroad track would pass over visual representations of ground features.

And remember, for pilots who yearn for VFR simplicity on those bright sunny days, all displays could be shut down while the central processing units continued to silently monitor engine status and position.

Naturally, since the conversation was homed in on microprocessors, no one around Rutan's conference table had any trouble getting rid of the control cables and pulleys usually found in airplanes. In fact, the fly-by-wire mentality that permeated the discussion was carried through to its logical conclusion when someone suggested using fiber optics cast into the structure for primary control. Input from the side sticks would integrate with the microprocessors, which would send signals through the photonics to small, inexpensive servo motors mounted in the control surfaces.

The concept of incorporating certain redundancies into the design surfaced throughout our discussion. Both Schirra and Tristani outlined the back-

(Please turn to page 100)

Remote Toxin Detector

EL SEGUNDO, CA—The Remote Active Spectrometer (RAS), being developed at Hughes Aircraft Co., will enable troops to detect chemical weapons up to 3 miles away. The detector bounces four infrared laser beams off a chemical cloud or pool. Each beam can be independently tuned to a specific frequency. Since any given chemical absorbs light at a characteristic frequency, the device can identify possible poisons by analyzing the unabsorbed infrared light that



RAS smells distant poisons.

the target reflects. The RAS is designed to replace hand-held detectors that only registered when a soldier walked into a toxic environment.

Digital Med Archiving

ISELIN, NJ—The Picture Archiving and Communication System (PACS) stores images from X-rays, CAT scans, magnetic resonance and other tests. Developed

by Siemens Medical Systems, PACS can sharpen features with an edge-enhancing filter or enlarge details with a "zoom" function. Looking at a PACS terminal instead of juggling files, doctors can use the simultaneous display to verify diagnoses.



Doctors compare PACS-stored images from different tests.

Floating Hotel Near Australia's Great Barrier Reef

QUEENSLAND, AUSTRALIA—The world's first offshore floating hotel is now anchored adjacent to Australia's Great Barrier Reef, 44 miles off the mainland. The 322,500-sq.-ft. Four Seasons resort features a desalination plant for fresh water, on-board sewage and waste treatment, an underwater observatory and a semisubmersible vehicle for coral-reef cruises, as well as the usual luxury hotel amenities.

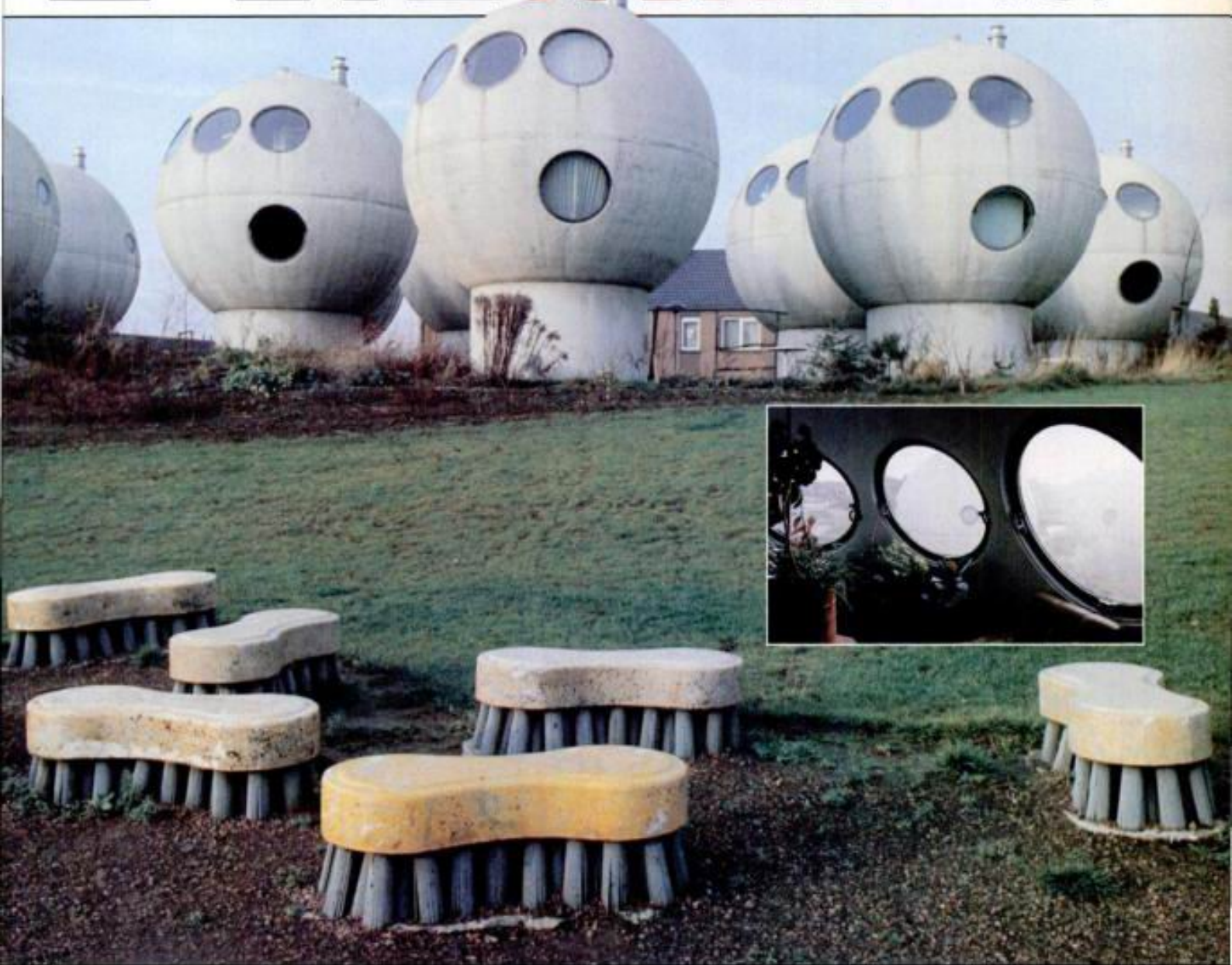
Moving the 7-story hotel building was something of an engineering challenge. Construction got underway in June 1986 in a Singapore shipyard. Last fall, engineers guided a

half-submerged, heavy-lift carrier vessel under the floating hotel structure and then pumped the carrier dry, raising the building out of the water. The ship brought the hotel to the lagoon and reversed the loading process. Work crews connected the hotel building with pontoons that carry tennis courts, a marina and the rest of the complex. Anchoring the whole resort is a mooring system originally developed for oil supertankers. The hotel's powerplant, according to the developers, will operate at almost noiseless levels so as not to disrupt the reef's delicate ecosystem.



Helicopters and high-speed catamarans will bring guests from the mainland to the floating hotel.

PM TECHNOLOGY UPDATE 7/87



People Who Live In Globe Houses

How do you reconcile the dream of living in detached housing in an increasingly crowded world? That's the dilemma that faced Dutch architect Dries Kreijkamp of Breda, The Netherlands. So Kreijkamp set out to maximize interior living volume and minimize exterior space. The result is the field of 85 globe houses sprouting on the outskirts of Hertogenbosch. "Basically,

the dwellings are meant for a maximum of two persons, plus a baby," Kreijkamp says, "and I emphasize the word 'baby.'" The 4-level globes measure 5½-meters wide and are made of a cement-reinforced plastic of Dutch manufacture called GVC. The walls are 10 centimeters thick and utilize a sandwich construction. The globes are placed on pedestals 2.5 meters high and 3

meters wide, requiring only 6.67 square meters of land. Tenants enter through the pedestal, which also contains a storage room and space for a heating plant. A staircase leads to a bedroom on the next level, and eating/living facilities on the top floor. Windows are 1.2 meters wide (inset) and round out the globular motif. They also contribute to the houses' passive solar characteristics.

Living in the round is one proposal for detached, multi-family housing. Architects say the multi-level design is adequate for a couple and a small child. Foreground, the whimsical touch of this Dutch housing project extends to the park benches—shaped like scrub brushes.

Editor: Tim Cole
Contributors: Theo C. Bensen,
Ed Valigursky, Ted
Francis, Carter Hilary

HOW WE'LL LIVE



NASA planners foresee a manned lunar base in the early 21st century. Why are we going back? And how will we survive when we get there?

BY ISAAC ASIMOV
PM Illustrations by Pat Rawlings

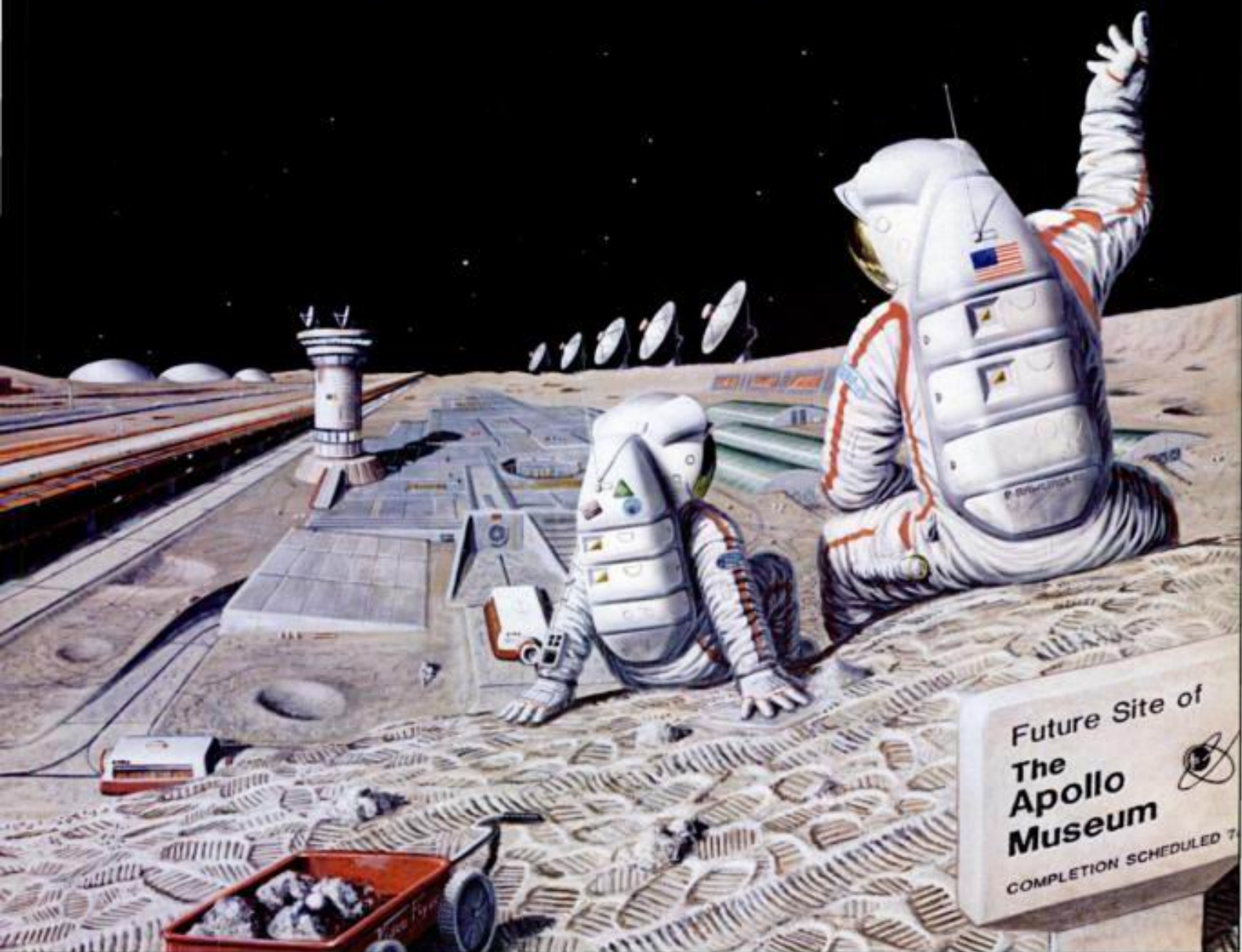
ABSOLUTE SILENCE. The Lunarian stood in the eternal dark within the crater at the Moon's south pole,

and thought that silence was what was so characteristic—and soothing—and, yes, frightening—about the Moon. He was not a true Lunarian, of course. He had come from Earth and when his 90-day stint was over, he would return to Earth and try to readjust to its strong pull of gravity.

There was no motion anywhere, no sound of living things. There was light along the crater top, as perpetual as the dark at this portion of the crater floor. Farther along the gently rolling floor, in the direction of the opposite side of the crater, was sunlight, too.

The Lunarian looked in that direction, and the photosensitive glass of his faceplate darkened at once.

ON THE MOON



The line between dark and light swung slowly toward him and away in a 4-week cycle. It would never quite reach the point where he was standing, nor ever quite recede out of sight. If he were to move a few miles into the light, he would see the Sun skimming the crater edge along the horizon, but, of course, the faceplate grew virtually opaque if he accidentally looked in the Sun's direction. At intervals, he could see the Earth, or a portion of it, edging above the crater wall. His heart would always melt at that sight. He tried not to think of Earth. For now, he was on the Moon. He could make out the line of photovoltaic cells in the sunlight and he knew that solar energy, never-ending, was

Two Lunarians contemplate Mother Earth from a crater rim overlooking an advanced Moon base. The facility boasts an electromagnetic tube launcher to hurl mined lunar oxygen into space, observatories and complex structures housing labs and life support. This vision could be reality by the end of the next century.

powering the world beneath his feet—which was, as yet, very small. Already, dozens of human beings were housed there and in his lifetime it might well rise to hundreds. An experimental farm existed there, plus a chemical laboratory for the study of lunar soil, a furnace for baking out the small but precious amounts of volatile elements from appropriate ores.

This was not the only Moon base. A much larger one

LIVING ON THE MOON

existed near the lunar equator, where the soil was mined and hurled into space to be used as a construction material. A much more specialized one existed on the Moon's far side where a huge radio telescope, insulated from Earth's radio interference by 2000 miles of solid Moon, was being completed.

The Lunarian thought: It is the year 2028 and the Moon has become our second world.

But it is now 1988. We have visited the Moon six times between 1969 and 1972, and 12 men have trod its surface. But those were visits only. We came, lingered and left—so that the total time human beings have spent on the Moon is less than two weeks.

But we have been sharpening our space abilities, and when we return to the Moon, it will be to stay. A day will come in the future after which there will never be a time when human beings will not be living on the Moon.

NASA is already planning Moon bases. In recent years, scientists, engineers, industrialists and scholars have met to discuss scientific, industrial and sociological issues in connection with living on the Moon. Former astronaut Dr. Sally K. Ride, America's first woman in space, recently produced a report outlining this nation's space goals. Satellite studies of the Earth will remain an important priority, along with the lofting of un-

manned spacecraft to explore our solar system. But the "Ride Report" also stresses a manned permanent presence on the Moon before we embark on a manned mission to Mars, hoping to fully exploit the Moon's resources and scientific opportunities—while boosting our own interplanetary learning curve—before engaging in a Mars space spectacular.

Whether or not we choose to follow the Ride recommendations, the Moon will probably play an important role in man's future space explorations. But

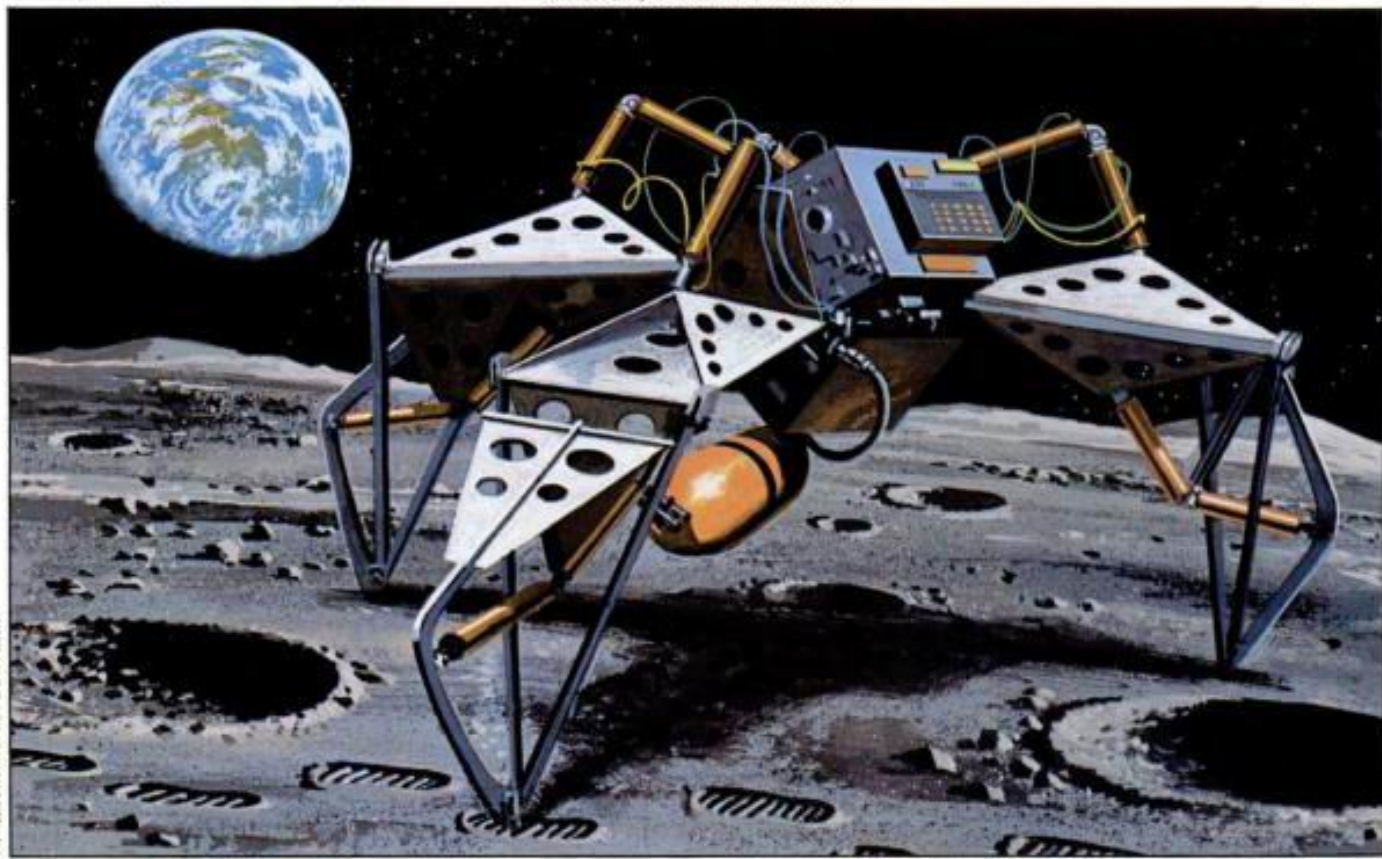


A lunar lander (above) delivers cargo pods to a future Moon base. To assist in lunar exploration, engineers at Georgia Tech have designed Skitter I (below) a 3-legged, all-terrain, autonomous robot.

why bother? The Moon is a dead, desolate world, without air or water. It is a large super-Sahara. So what is there to make us want to go there, let alone live there?

Super-Sahara or not, the Moon would be useful, even vital, to us in many ways. Some of those ways are not material in nature. For instance, there is the question of knowledge. The Moon has not been seriously disturbed after the first half-billion years of the existence of the solar system (something that is not true of the Earth). We have been studying 800 pounds of Moon rocks astronauts retrieved, but merely bringing them to Earth has contaminated them, and the astronauts were only able to investigate isolated landing areas. If we can investigate the Moon's substance on the Moon, over extended periods and over every portion of its surface, we might learn a great detail about the early history of the Moon—and, therefore, of the Earth as well.

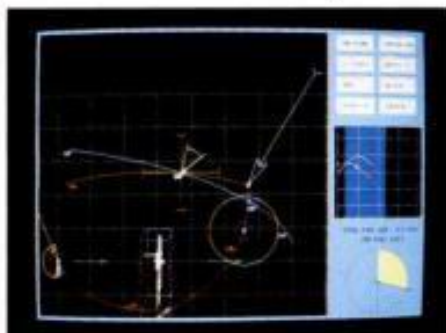
Unlike man's initial forays to the lunar surface, future trips to the Moon will be greatly aided by a space station positioned in low Earth orbit, by orbital transfer vehicles and by expendable lunar landers. It's envisioned that early lunar pioneers will reside in pressurized modules and airlocks—not unlike the modules currently being designed for the space station—but with a significant difference. Because the Moon has no protective atmosphere, early settlers will cover their modules with up to 2



Space Traffic Control

MOFFETT FIELD, CA
—Controls for maneuvering spacecraft in the vicinity of

cles' positions in a modified 3-dimensional perspective based on information from radar and lidar sensors on board the spacecraft. The view is distorted to compensate for the brain's reconstruction of 3-dimensional information derived from a flat surface. Objects out of visible range are magnified. It also has a zoom capability for



Computer graphics show distances.

the Space Station will include this display concept developed at NASA's Ames Research Center.

The monitor depicts vehi-

close-in maneuvering. The system will allow controllers to direct orbital maneuvers on a spur-of-the-moment basis.



Shuttle-2, designed to fly in the 21st century.

Shuttle For The Future

HAMPTON, VA—NASA is increasingly concerned that the Space Shuttle will be nearly 20 years old by the time the Space Station becomes operational in the late 1990s.

Studies under way at Langley Research Center

point to a second-generation Shuttle that will feature a modular, removable payload pod, wing-tip fins and long-life main engines. A winged flyback booster would replace the external tank-solid rocket booster combo that lofts today's Shuttle.

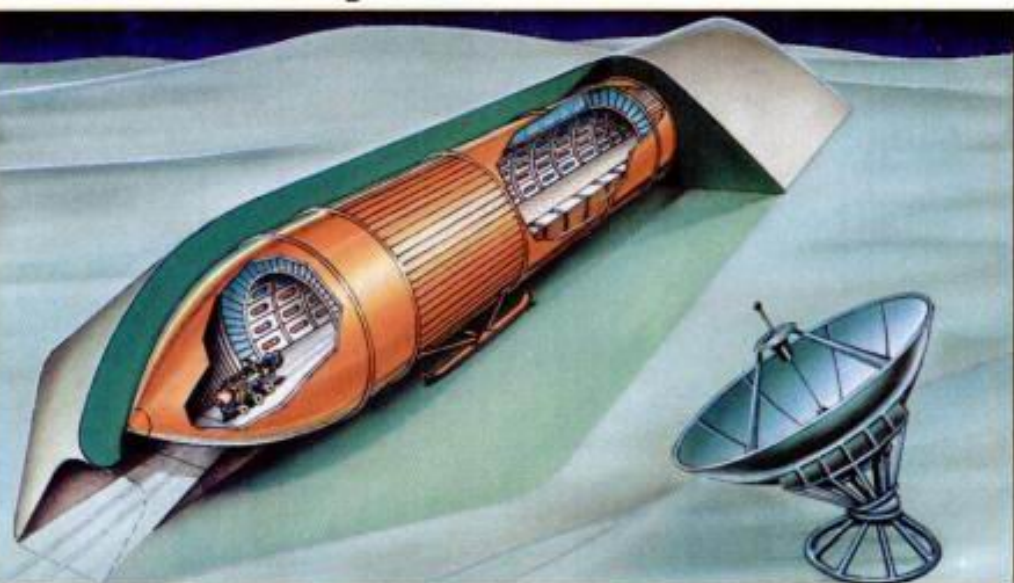
External Tanks Turn Into Space Labs

CITRUS HEIGHTS, CA
—With the Shuttles back in service, private businesses have renewed interest in the external fuel tanks jettisoned by Space Shuttle orbiters after takeoff. NASA will be putting about 40 tanks up for grabs through 1994.

Commercial space firms have proposed the tanks be converted into everything from gamma ray telescopes to orbiting industrial platforms. Typical of how commercial space entrepreneurs are reacting is a proposal by Wickman Spacecraft & Propulsion. The rocket-fuel manufacturer wants to yoke two tanks to create a microgravity research facility in geosynchronous orbit.

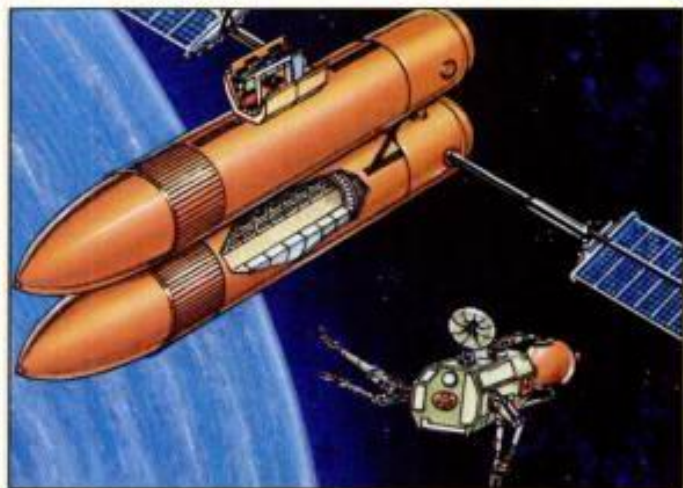
An expendable rocket will launch a robotic vehicle, Astrobot, equipped with manipulators and the experimental equipment. Astrobot will link the tanks, pad the tanks' interiors with insulation and install the apparatus. The vehicle will be able to respond to Earth-base commands and will remain in orbit to monitor experiments.

Meanwhile, Wickman has also expressed interest in landing three tanks on the Moon. Converted and ser-



Roving astrobot (above) will bury lunar tank conversions for insulation from solar radiation. Space-based astrobot (right) will co-orbit with microgravity-lab tanks, shuttling specimens between experiment modules.

viced by a wheeled Astrobot, the tanks would serve as research facilities for processing lunar soil for oxygen, concrete and other necessities. One of the tanks would be outfitted for human habitation prior to establishment of a permanent manned lunar base.

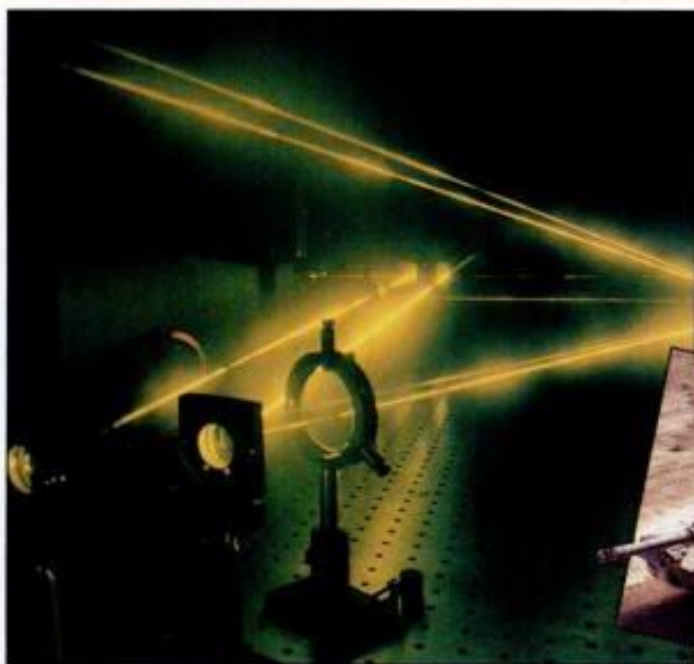


Identifying Tanks In War

STERLING HEIGHTS, MI—As tank evolution continues its course of copycat one-upmanship, target identification systems are growing in importance.

Increasingly, visible-wavelength lasers are the method of choice. Lasers used for rangefinding usually operate in the invisible infrared range for obvious reasons. General Dynamics is experimenting with dye lasers that fire in conjunction with optical crystals which also operate the system's optical computers. In this way, the system uses light, instead of electricity, to process signals.

General Dynamics research strides in battlefield



General Dynamics' electro-optical tank identification technique could be fitted into a fire-control system for an advanced M1A1 version if experiments prove fruitful.

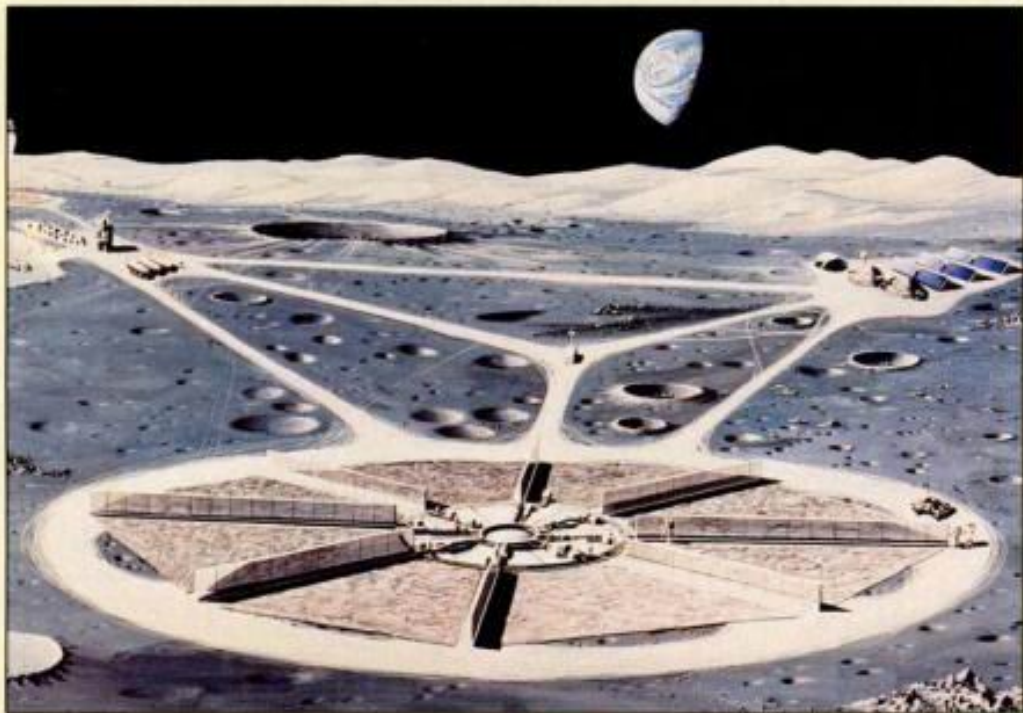
lasers is only one example of the intriguing possibilities that have been presented to military users.

Optic Electronic Corp. has developed an eye-safe laser targeting and ranging system for troop training.

On the defensive side, Perkin Elmer is working on a laser warning receiver to protect against laser-guided weaponry.



GENERAL DYNAMICS PHOTOS



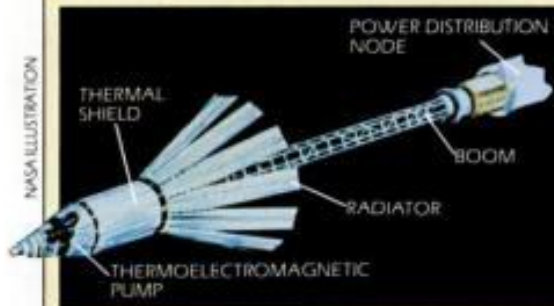
Space Power Needs

CLEVELAND, OH—Options for space power generation continue to multiply. One NASA contractor, Mechanical Technology, Inc., is developing a 25-kilowatt generator based on the Stirling engine. A technology demonstrator model is already functioning.

Inside a Stirling engine, gas expands and contracts as heat is added and removed. Pistons inside sealed cylinders are moved by the changes in gas pressure. Stirling's advantages include a lack of wearing parts and excellent efficiency.

Meanwhile, NASA continues to explore the possibility of using small nuclear reactors as orbiting power sources. The SP-100 consists of a small reactor core surrounded by heat-dissipating fins. The reactor and attendant thermal control units are separated from the distribution and control system.

All space-based power concepts have a single design imperative. They must be light enough for easy lofting, yet capable of generating significant wattage for man's future space explorations.



Stirling generators, such as working prototype at right, could form lunar powerplant (above). NASA's SP-100 relies on nuclear energy to satisfy space power requirements.

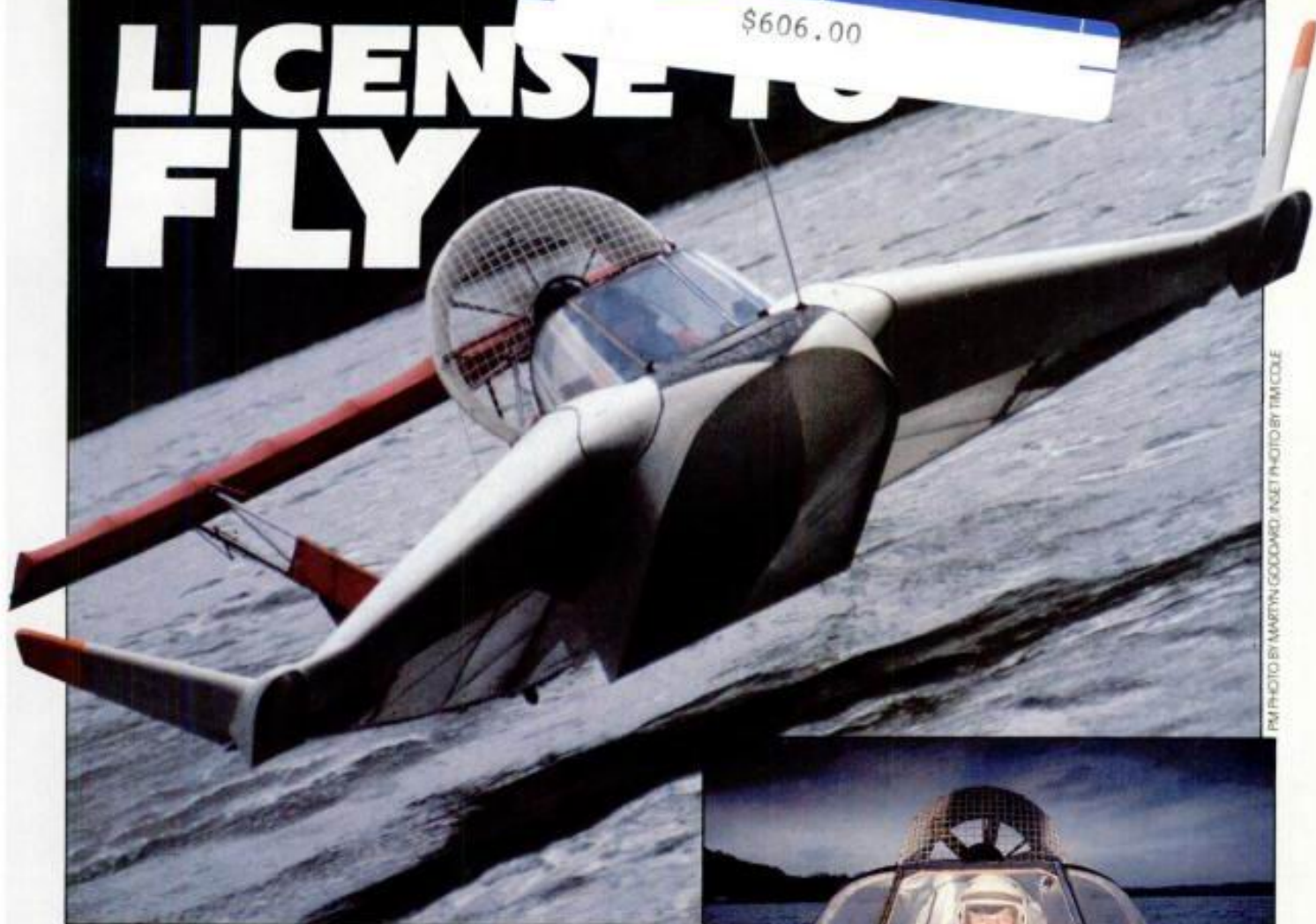
NASA ILLUSTRATION

NASA ILLUSTRATION

MIT PHOTO

LICENSE TO FLY

\$606.00



Part boat, part bird, this new ground-effect vehicle will speed you over the water. And you don't need certification to operate it.

BY TIM COLE, Science/Technology/Aerospace Editor

LOCAL guides call it The Back Country, maybe the "nether-est" of fishing's nether regions. But this clutch of islets and outcroppings scattered at random throughout the Bay of Florida is also where the fish are. Snappers. Jacks. Bonefish. Tarpon. They congregate at the end of a punishing 3-hour journey by center-console boat, through infrequently traveled, dangerously shallow waters. Just getting to the fish, let alone getting the lines wet, is an all-day affair.

But on this particular day in the summer of 1990, we're compressing the time and distance between fishing hole and frying pan with a flying fish of our own—an airfoil boat designed to traverse great expanses of water with unheard of speed, range, carry-

ing capacity and comfort. We're at the controls of a flarecraft, a new kind of flying machine that bridges the existing technologies for traveling over the water and through the air.

A revolutionary ground-effect vehicle built in West Germany and scheduled to enter the U.S. market next summer, the flarecraft flies on a dynamic air cushion just off the surface of the water, like a swan or a pelican. Hovercraft, also relying on the ground-effect phenomenon, have lift engines that furnish a static air cushion. Flarecraft fly much faster and more efficiently using far simpler construction and propulsion. The pressure created by the flarecraft's patented wing shape captures and compresses air against the water (or

The prototype flarecraft skims a German Lake. Its single-place cockpit (above) will have room for two in a future version.



mud bank, or shoal, or coral reef), which, augmented by the natural forces of aerodynamic lift, levitates the craft in a highly stable, usually swift sea-skimming flight. But you can't really call it flying, because the wing remains in a semistalled condition: Hence the term flarecraft, a word that developers hope will join the lexicon of transport along with trains, planes and automobiles.

In truth, according to aerodynamic designer John Roncz—creator of the airfoils for Burt Rutan's world-girdling *Voyager* and Beechcraft *Starship I*—a flarecraft is a technology that borrows from boats in slow-speed displacement mode, and aircraft, when it flies over the wavetops.

LICENSE TO FLY

PHOTO BY MARTIN GOODMAN



AIRFISH II

Airfish II reveals reverse-delta, reverse-dihedral planform and large tail structure.

"Airplanes are getting too expensive when you consider costs of operation, let alone the costs to certify. Boats are heavy, uncomfortable in a seaway, and hardly fuel efficient. Ground-effect technology in these so-called flarecraft has so many advantages over all prior methods of moving across water."

Like many other visionaries, Roncz foresees a time when flarecraft will economically replace the kind of large-scale hovercraft that link England and Europe.

"I can see huge flarecraft carrying cargo across the Earth's oceans. Right now, there are no real obstacles," says Roncz.

The drawing board

Although Roncz's vision need not await enabling technologies, organizations with the required funding and

drive to harness the ground-effect phenomenon haven't materialized—until now.

Entrepreneur Bill Russell of Westport, Connecticut, recently founded Flarecraft Corp. to exploit ground-effect technologies. The company has entered into an agreement to market a 2-place recreational flarecraft, which will be produced by Messerschmitt subsidiary Rhein-Flugzeugbau (RFB) outside Düsseldorf. RFB's technical director, Hanno Fischer, is currently evaluating power and control issues aboard a prototype called Airfish II, the engineering test bed for the 2-place production machine that the team has tentatively dubbed Airfish III. His test tank: the sylvan waters of Lake Baldeney, home of the Krupp family dynasty.

"Ground-effect craft are a whole new transportation system," Russell

confidently asserts.

"We're just seeing the beginning of it now, but the advantages in terms of payload, fuel efficiency, range and comfort are clearly there."

Best of all, Russell says, flarecraft are not considered aircraft. According to a recent FAA ruling, the craft is incapable of free flight in federally controlled air space. It depends on the ground to achieve the ground-effect pressure necessary to create the dynamic air cushion. Indeed, according to Roncz, the ground-effect craft's induced drag increases with altitude, making sustained high-level flight impossible.

"The environment in which it would operate would be more similar to that of a surface vessel," according to the FAA's Boston-based John Markunas.

Russell is banking on that ruling to introduce the freedom of flight to po-

\$1612.25 Double Spread

HORIZONTAL STABILIZER
RUDDER (2)
TWIN VERTICAL STABILIZERS

Two Decades Of Ground-Effect R&D



X-113



X-114



AIRFISH I



FUTURE COMMUTER

The West German government subsidized X-113 and X-114 to test the military applications of ground effect. The X-113 was a center-fuselage trimaran design. The catamaran X-114 suffered a reduced payload. Designers reverted to the trimaran design for

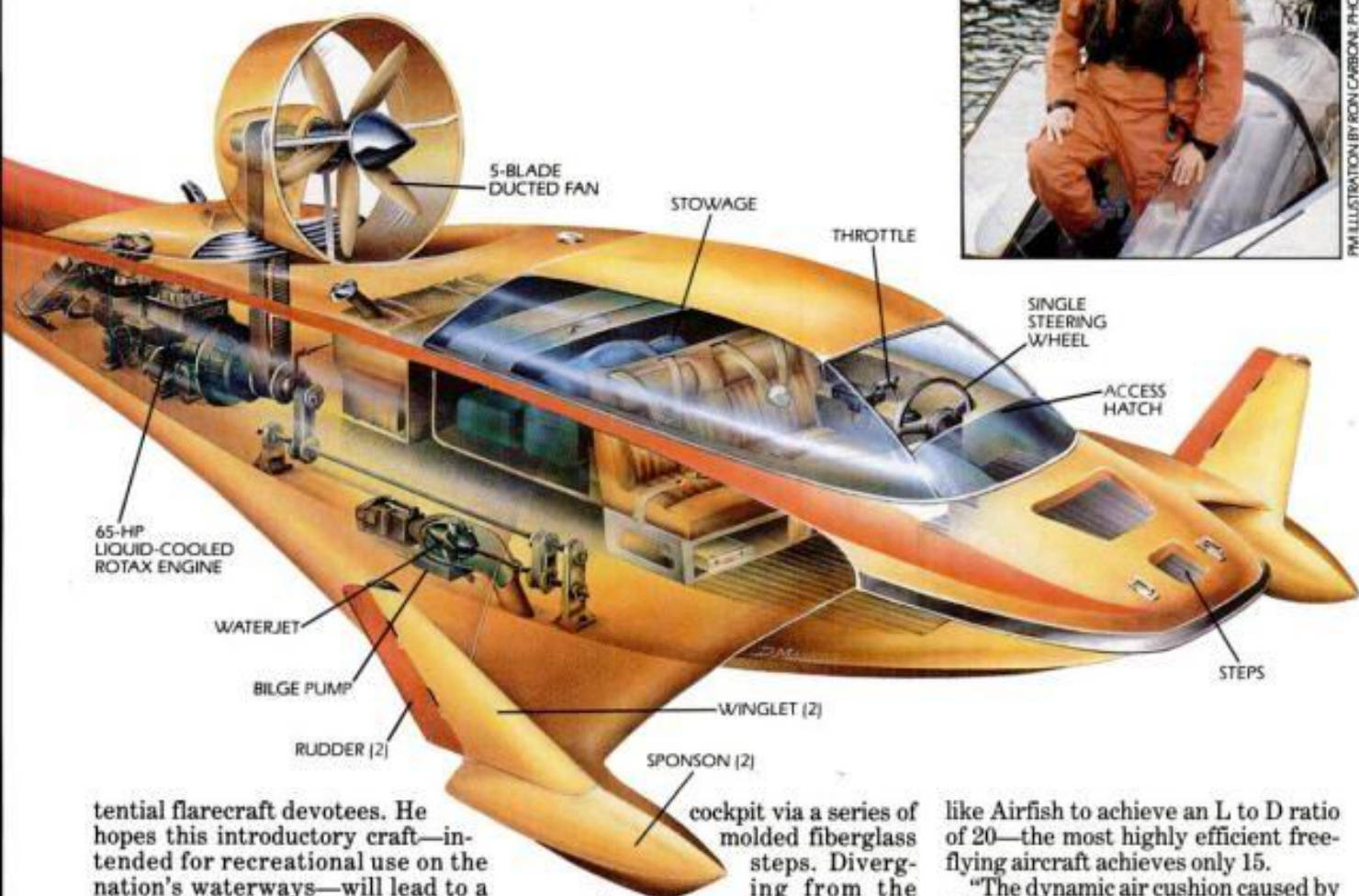
the ultralight Airfish I. The end result may be a flarecraft commuter version. The future commuter, envisioned by Flarecraft Corp. and Germany's RFB concern, would be an 8-passenger design with enough room for cargo, too.

TOMORROW'S FLARECRAFT

The 2-seat flarecraft, scheduled for introduction in the summer of 1990, will incorporate the Lippisch flarecraft design refined by designer Hanno Fischer (right) of Rhein-Flugzeugbau. A 65-hp liquid-cooled Rotax will power the vehicle, which also incorporates a small jet drive for slow-speed maneuverability.



PHOTO BY RON CARROLL PHOTO BY TIM COLE



tential flarecraft devotees. He hopes this introductory craft—intended for recreational use on the nation's waterways—will lead to a series of larger flarecraft for commuting, general transport and commercial cargo hauling.

As currently planned, the production 2-place flarecraft will be 34 ft. 6 in. from nose to tail and have a wingspan of 20 ft. Folding winglets will reduce the beam while the vehicle is moored. The main wings are removable for trailering.

Fischer is currently experimenting with a 90-hp horizontally opposed 4-cylinder Hirth engine aboard Airfish II. Airfish III will likely carry a 65-hp liquid-cooled Rotax that will be clutched to a small jet drive for slow-speed maneuverability in congested harbors. A maximum payload of 550 pounds is envisioned, which would be comprised of two passengers, their baggage, instrumentation and fuel. The sport flarecraft will be capable of a 300-mile range at a cruising speed of 72 mph.

Four-point harnesses will restrain the vehicle's dual occupants, who will enter the craft over the bow through a windscreen hatch and descend to the

cockpit via a series of molded fiberglass steps. Diverging from the conventional, the ground-effect craft will have no stick and no rudder pedals. A single steering wheel will link Airfish III's control surfaces—twin rudders on the twin vertical stabilizers aft, and twin rudders on the craft's pontoon-mounted winglets port and starboard. A single throttle positioned boating-style on the crash pad to the left of the operator will power the flarecraft onto a plane. Once a certain airspeed is achieved, Airfish III will go airborne without any deflection from the controls. Once in ground effect, the flarecraft can be banked into tight turns, and throttled back to cruising speed.

"We can fly five times faster than a ship at half the power," Fischer proclaims. "Airfish I, our previous test bed, achieved 100 km/hr. after we throttled back to an effective shaft output of only 15 hp."

New efficiencies

The real advantage is in the traditional aerodynamic value of lift to drag. It's not uncommon for an airfoil boat

like Airfish to achieve an L to D ratio of 20—the most highly efficient free-flying aircraft achieves only 15.

"The dynamic air cushion caused by the flarecraft flying over the water also gives automatic stability," Fischer says. "The closer you come to the ground, the more dense the air cushion becomes. The vehicle consequently develops more air loads on the wing surfaces and more height-sustaining pressure. You achieve a kind of equilibrium status and you can fly hands off close to the ground with peak efficiency."

For all its futuristic implications, Airfish III's roots go back to the early '30s, when a Finnish innovator employed ground effect to move a heavy sledge across a series of frozen lakes. A tractor-mounted propeller engine supplied the motive force, augmenting the air cushion beneath the craft. Soon, the rudimentary vehicle manifested a destabilizing pitch-up at high speeds—exhibiting a pesky glitch that would plague future ground-effect efforts. The Finnish solution: Trail a ski to counteract this rather unhealthy tendency.

German aerodynamicist Dr. Alex-

(Please turn to page 124)

Shuttle for tomorrow's

EXTERNAL PROPELLANT TANK:
(187 feet in height, 26 feet in diameter)

SOLID ROCKET BOOSTER

REINFORCED
CARBON-CARBON
COMPOSITE

REACTION-
CONTROL
ENGINES

AIR LOCK

MISSION
CREW

CREW
COMPARTMENT:
FLIGHT
CONTROLS

FLIGHT CREW

AIR-BREATHING
ENGINE
TO BE DEPLOYED
FOR ATMOSPHERIC
FLIGHT

EARLY THIS MONTH, if all goes well, a mighty Saturn will roar skyward from its pad at Kennedy Space Center (Fla.), spewing white flame and making the ground tremble for miles around. In the rocket's nose, strapped into seats in the command module, will be the last three Earthmen the moon will see for some time. Apollo 17 is the final mission in the most spectacular program of exploration in history.

But that does not mean the end of manned space efforts by the United States. There are Skylab, a space laboratory scheduled to be put into Earth orbit in 1973, and the Space Shuttle, which should be operational by 1980.

The Shuttle is our newest space program. The prime contractor—North American Rockwell, Downey, Calif.—was named by NASA just last summer. At this writing, there are still some design details awaiting a final decision.

The Shuttle program has two primary goals: to make space flight as routine as possible and to cut the

REINFORCED
CARBON-CARBON
COMPOSITE

SOLID ROCKET BOOSTER
3.5-MILLION POUNDS THRUST
(150 feet in height, 13 feet in diameter)

MAIN ENGINE
(ONE OF THREE;
EACH DEVELOPS
470,000 POUNDS
THRUST IN SPACE)

ORBIT-
MANEUVERING
ENGINE
AND REACTION-
CONTROL
ENGINES

ROCKET MOTOR
FOR MISSION-ABORT
CONDITIONS

By 1980, commuting to near-space may be routine. We have the know-how —now we're working on the hardware.

*Technical art by
Peter Trojan*

space commuters

By JOHN F. PEARSON
Science Editor

cost of putting payloads into space. It's estimated that the cost of putting one pound of payload into a low-Earth orbit with current launch vehicles costs a minimum of \$900. With the Shuttle the cost would drop to about \$160.

In contrast with all other space-flight systems, the hardware for the Shuttle will be reusable and will not require the elaborate and time-consuming preparation for launch that now is customary.

The key unit will be the orbiter, a delta-wing vehicle about the size of a medium-range (DC-9) jetliner. It's designed to function both as a rocket and as an aircraft—it's the first vehicle of its kind.

The orbiter will have a crew of four—a pilot and copilot, and two mission crewmen—and will be able to carry about six passengers. Large pieces of equipment—satellites, space "tugs" or even fully equipped labs—can be carried in the orbiter's payload bay, which is 60 feet long and 15 feet in diameter. The craft can carry 65,000 pounds of cargo into orbit and bring about 40,000 pounds back to Earth.

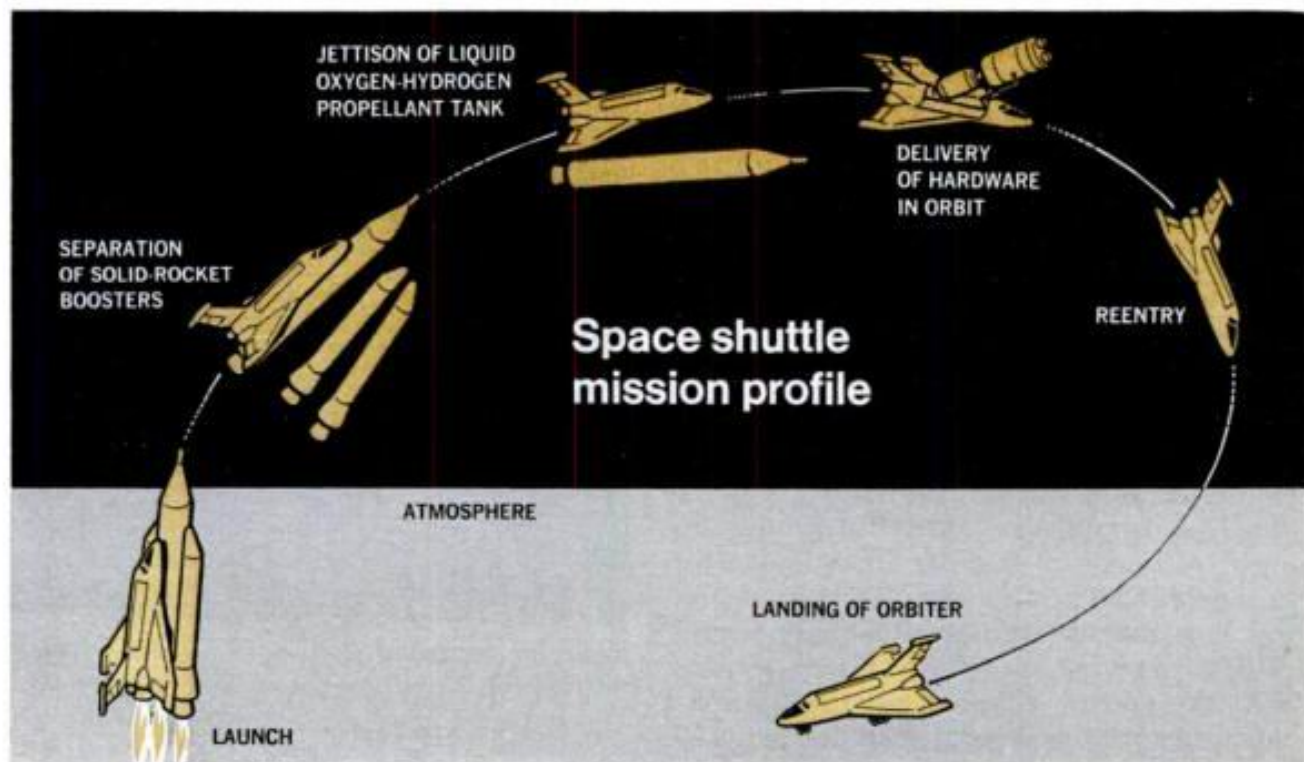
Power to get the 140,000-pound orbiter

off the ground and into orbit—100 to 260 nautical miles above the Earth—will come from two solid-rocket boosters and three big rocket engines in the orbiter's tail.

The 150-foot-long solid rockets will each develop some 3.5 million pounds of thrust. They will detach at an altitude of 25 miles and descend by parachute for recovery in the ocean.

The orbiter's three rocket engines will be fed fuel—liquid oxygen-liquid hydrogen—from a tall propellant tank, enabling each to pour out 470,000 pounds of thrust. On the pad, the 187-foot propellant tank will tower over its piggyback "rider," the orbiter, and the twin boosters. When the spacecraft achieves orbit, the propellant tank will be jettisoned, destined for ultimate destruction as it plunges through the atmosphere.

In space, the orbiter maneuvers by means of smaller engines in the rear propulsion cluster and makes course corrections by bursts of power from small thrusters nestled in the tips of the delta wing and atop its tall tail. A routine mission, according to space scientists, would last seven days. Extra expendable sup-



plies—food, water, oxygen—could extend the mission.

The orbiter's center section is taken up by the 60-foot bay. According to the present design of the vehicle the "roof" of the bay will consist of a pair of clam-shell doors that open outward to permit deployment of a payload or taking cargo aboard.

One of the orbiter's chief tasks will be to place a whole zoo of satellites in orbit. They would include communications, weather, navigational and air-traffic control, earth resources and geodetic satellites. It would also orbit space probes and special-purpose observatories.

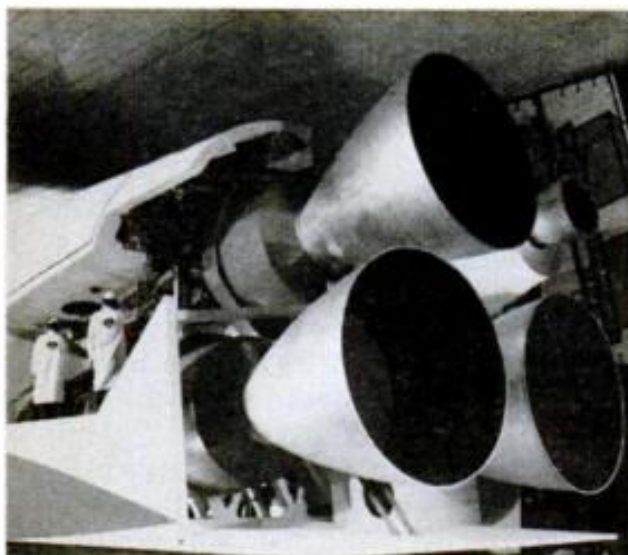
One already on the drawing board is NASA's Large Space Telescope, a bruiser about 50 feet long and weighing up to 25,000 pounds. The 'scope reportedly will be able to look at galaxies 100 times fainter than those seen by the most powerful Earth-based optical instruments. Within the solar system, it will be able to provide long-term monitoring of atmospheric phenomena on Venus, Mars, Jupiter and Saturn. In addition to launching the big space eye, the orbiter would be able to retrieve it for repairs and updating of its instruments.

The orbiter will have the capability of retrieving hardware in near-Earth orbit. Today, many automated satellites never function after they're orbited; others fail after some time. An antenna may fail to unfurl or a battery charger may malfunction, causing a loss of power.

To retrieve an ailing satellite, the orbiter would rendezvous with it. Engineers dressed in space suits would pop out through the clamshell doors and put lines on the satellite. It would be hauled into the payload bay for examination. If the trouble were minor, a repair might be made on the spot and the satellite re-deployed. But if a big repair were required, the satellite would be returned to Earth. This capability would save considerable money, say NASA officials.

Another function of the new vehicle would be the deployment of a space "tug"—a propulsion unit that would be used to jockey a satellite from one orbit to another. The tug would operate on commands from the orbiter and would return to it when its job was done.

At the end of a typical seven-day mission, the orbiter would head for home—



ORBITER'S POWERFUL TAIL CLUSTER is seen in full-scale mockup created at North American plant



TYPICAL DELIVERY: Drawing shows how space tug would maneuver satellite payload away from orbiter



PILOT IN COCKPIT of orbiter simulator "flies" the big craft in for a power-off landing at air base

a landing strip at Kennedy Space Center or perhaps a base in California. Using rocket power, the orbiter descends until it reaches an altitude of about 400,000 feet. Here, in the Earth's upper atmosphere, the orbiter's aerodynamic surfaces and controls take over. The ideal descent will be completely unpowered. (The final decision on how the orbiter's air-breathing engines will be used was not made when *PM* went to press. It's possible they'll be used only for ferrying operations.)

Here's how NASA experts envision a typical landing sequence: At 39,000 feet the pilot engages the automatic landing system. The craft goes into a curving descent to an invisible "gate" at about 20,000 feet and some 20 to 30 miles from the landing point. At the gate the orbiter steadies into a steep, 6000-foot-per-minute, 300-knot glide. About 45 seconds before touchdown, the nose comes up and the craft settles down for a smooth landing at about 160 knots.

Such landings have already been made with experimental aircraft. Most of the electronic equipment needed to make automatic landings already exists in commercial jet transports. These systems are known to pilots as INS (Inertial Navigation System), DME (Distance Measuring Equipment), VOR (VHF Omni Range) and the ILS (Instrument Landing System). They furnish guidance and navigation information to the jetliner pilot, who uses it in flying his plane. The new NASA system uses the electronic devices to furnish guidance and navigation information to a computer, which directly controls the aircraft.

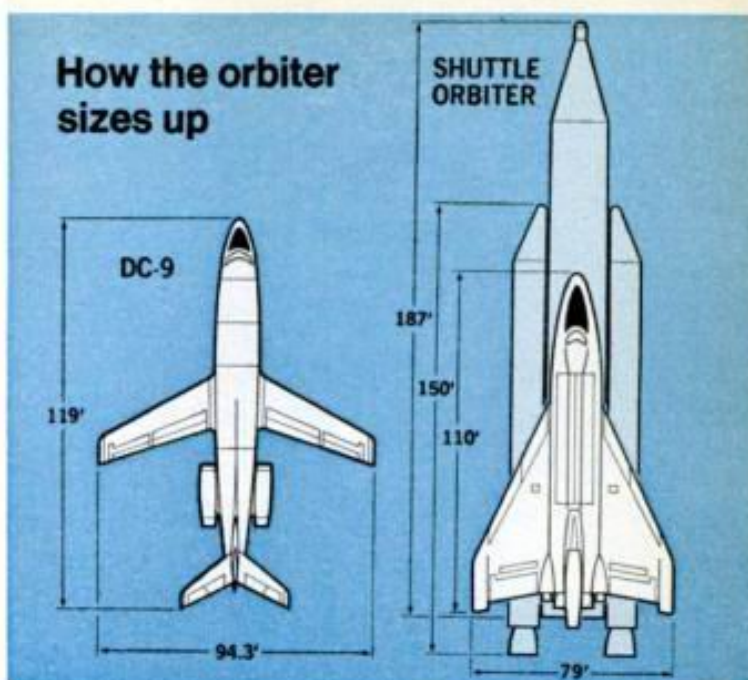
Since the orbiter will be serviced much like an airplane, it will have a turnaround time of about two weeks. Key to this short time is the new thermal protection it will have.

The heat shield protecting the Apollo capsule works well in carrying away the extreme heat developed during re-entry. The only problem is that the heat shield chars and melts away in the process. To replace it on the orbiter would mean considerable time and expense.

North American's scientists propose to create a permanent shield for the orbiter. The system will involve these elements:

- A low-weight elastomer (rubberlike material) that will be bonded to the 29

DECEMBER 1972



THOUGH ALMOST the same size, the 140,000-pound orbiter will outweigh the jet by some 80,000 pounds

percent of the orbiter structure that does not experience ultrahigh temperatures (less than 650°F.).

- A ceramic insulation bonded to the 68 percent of the orbiter surface that undergoes temperatures from 650° to 2500°F.

- Another new material (called a reinforced carbon-carbon composite), which will be used for the leading edges of the wing and the orbiter's nose cap, where temperatures of 3000°F. may be reached.

Plans call for each orbiter to be used 100 times or more. This will be a big factor in keeping the cost of each flight down to \$10.5 million, a reasonable sum where space operations are concerned.

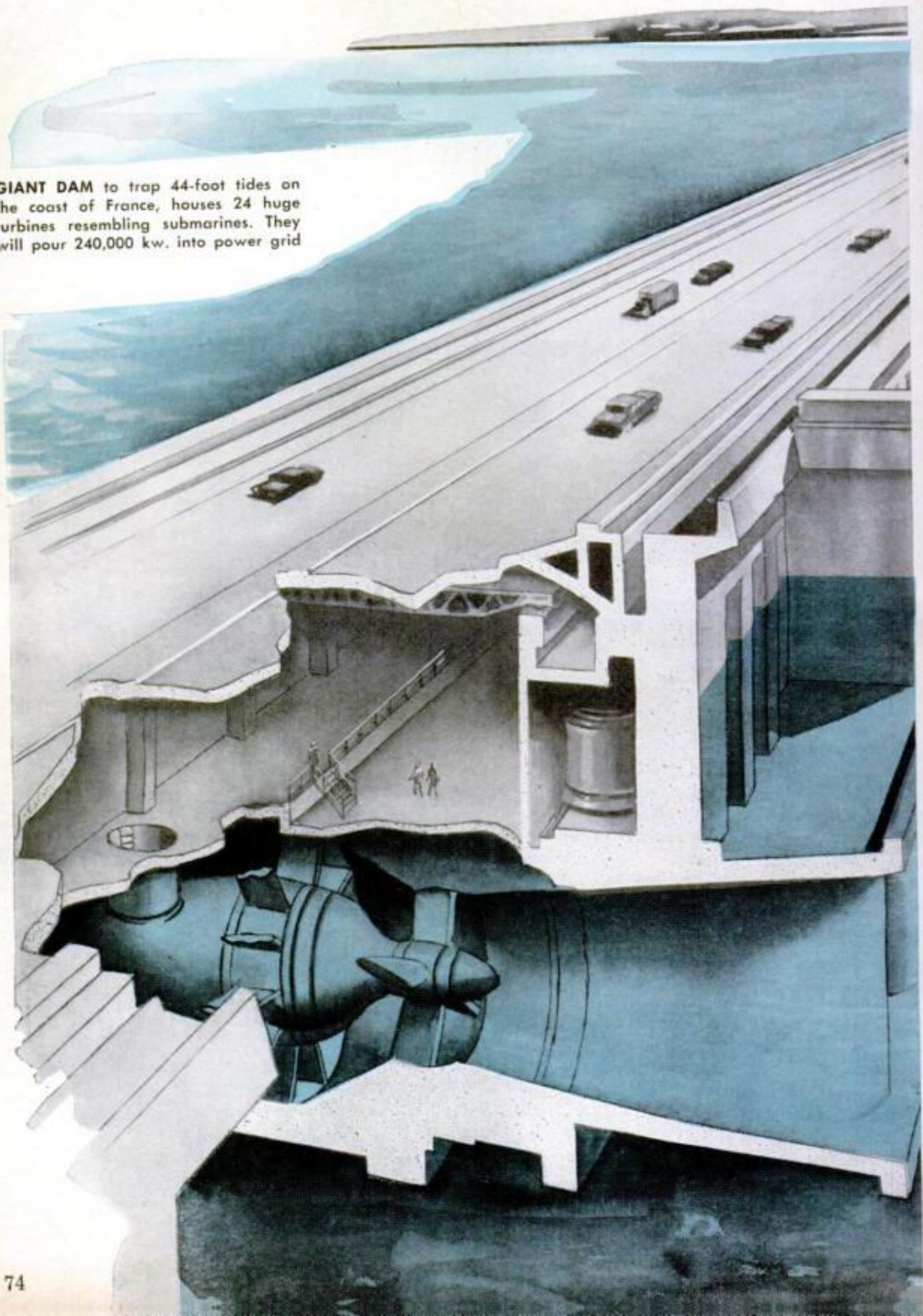
The Shuttle will be developed over the next six years. Horizontal test flights (using air-breathing jet engines) are scheduled to begin in 1976. Manned orbital test flights are planned for 1978, and the complete Shuttle system is to be operational two years later.

The system brings the day closer when the ordinary person—and not only the trained astronaut—can experience space flight. The Shuttle will have "controlled" liftoff that won't subject passengers to heavy "G" forces. Ultimately, the shuttle will carry scientists, physicians and lab technicians—both men and women—into space along with their experimental hardware. When this is an accomplished fact, the avid American tourist will surely start thinking about that one "place" he has yet to visit: space.

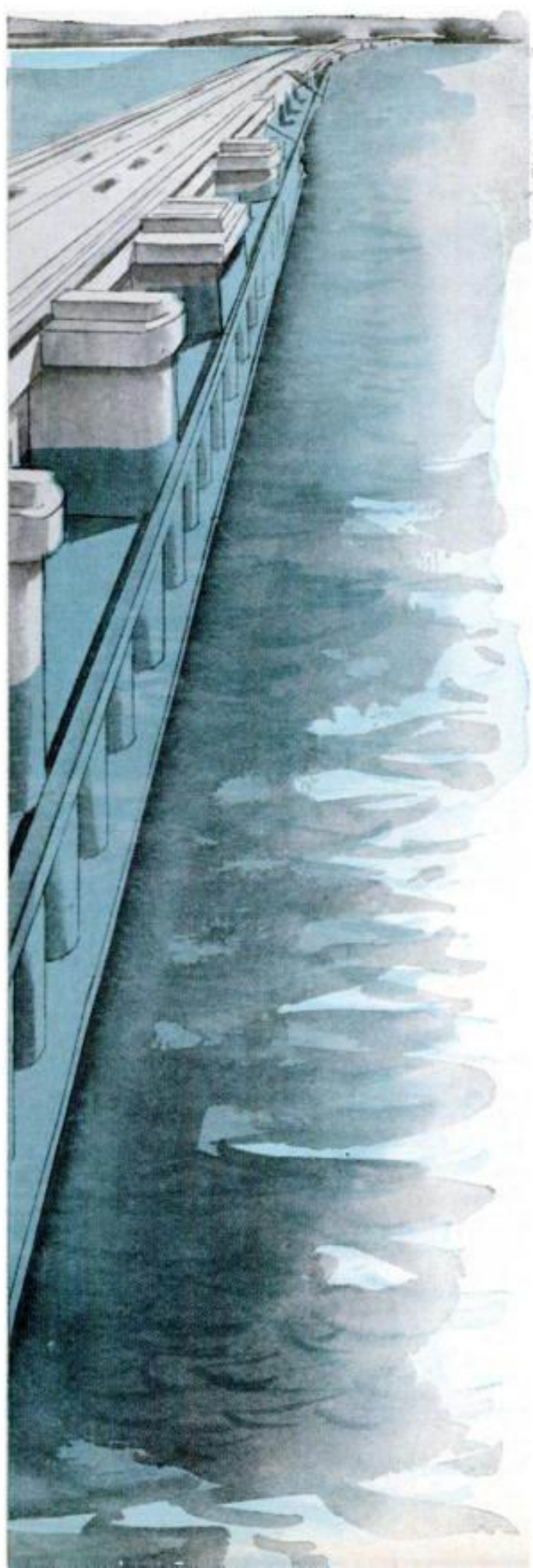
★★★

Moon Power for

GIANT DAM to trap 44-foot tides on the coast of France, houses 24 huge turbines resembling submarines. They will pour 240,000 kw. into power grid



the Lights of Paris



The dream of harnessing the tides to produce electricity is becoming fact in northwest France

By Harland Manchester

FOR MORE THAN 200 years men have talked of harnessing the rising and falling ocean tides to power their industry. Now, near the ancient French town of St. Malo on the English Channel, where the Coast of Brittany is pierced by the Rance River, one of the century's great engineering feats is nearing completion.

In the deep valley from St. Malo a corps of 900 workers has created a great reservoir extending almost to the city of Dinan, 15 miles upstream. Its purpose is to impound the formidable channel tides and route them through ingenious new turbines to produce electricity. And near St. Malo, engineers from the state-owned power system are building a \$90-million tide-powered hydroelectric plant to help light the lamps and drive the machines of their rapidly progressing nation.

The St. Malo site has long tempted power experts because its tides are among the highest in the world. The channel coasts of France and England shape the incoming Atlantic waters like a hydraulic engineer's dream, breaking them against the 90-mile-long Cotentin Peninsula which stands at right angles to their march. Buffeted back, these waters swell and sometimes raise the sea level as high as 44 feet. Twice a day the sea surges up the Rance River to Dinan, reaching a maximum volume of some 280 million gallons a minute, then withdraws, leaving a long, slender triangle of barren gray basin behind.

For centuries, Breton millers on the river's inlets have utilized dribblets of the great flood. Such a mill, now inactive, can be seen near St. Malo. The high tides passed through one-way gates to fill their millponds; then, as the water drained off during the ebb period, it turned waterwheels to grind the grain of local farmers.

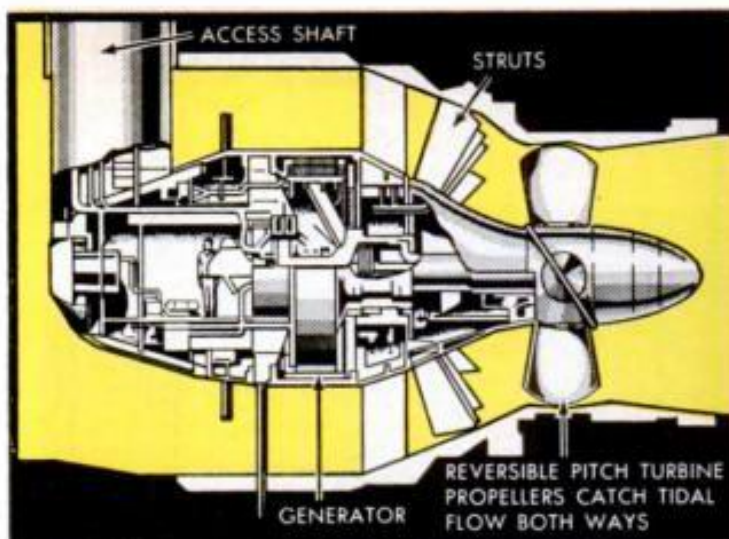
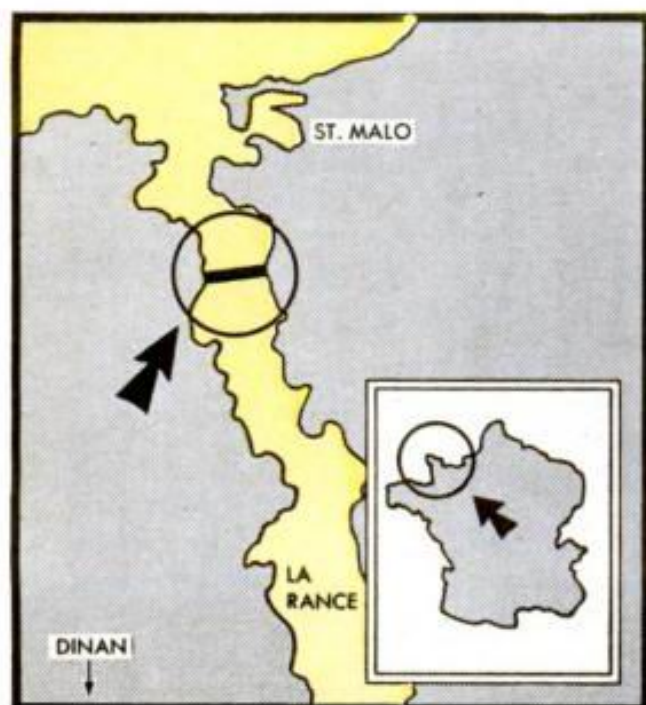
Ever since a French military engineer named Bernard Forest de Belidor first got the idea in 1737, occasional "visionaries" have been proposing methods for

harnessing the tremendous wasted bounty of tidal energy for industrial purposes. One of the plan's most tenacious and competent advocates, a dynamic 60-year-old engineer named Robert Gibrat, has succeeded after a 20-year campaign in persuading his technical colleagues and the men of money that the old dream would pay off.

The son of a Brest physician, Gibrat rambled the rugged Breton coast as a boy and was hypnotized by the savage power of the tides. He is a lifelong student of all methods of power production, and at 36 he became Director of Electricity Distribution of France's Ministry of Public Works. With little time for speculation during week day business hours, he went to his office one October Sunday in 1940 to look over some old files which had aroused his curiosity. There he found a dusty folder of shelved tidal power-plant proposals, among them a scheme for harnessing the tides near his native Brest. The deeper he delved, the more excited he became, and he paced the floor for hours weighing the problems and potentialities involved, and making notes on possible sites.

After studying maps of coasts and currents and tidal data, he concluded that St. Malo was the most admirable tidal energy site. He designed a hydroelectric system to harness both incoming and outgoing tides,

GIANT TIDAL DAM, world's first, is below St. Malo on the Rance River in northwest France. Tides formerly swept upstream 15 miles to city of Dinan



POWER UNIT resembles pot-bellied submarine and features giant propellerlike reversible turbine; 24 of them will be located in central part of dam



COFFERDAM under construction, showing cylinders of lower wall of oval lake being put in place. In foreground is six-gate sluiceway to help control tides

to drive turbines for the generation of power.

Now Gibrat organized a private industrial research group to conduct studies and promote the project. This group, later incorporated in Electricité de France, with Gibrat as consulting engineer, pursued an intensive program to design components for the revolutionary plant. To aid in solving problems never met before, an accurate scale model of the entire tidal basis was first constructed in a huge laboratory at St. Malo. There the banks and bed of the Rance are meticulously reproduced in concrete in a miniature river system 490 feet long. Every rock, shoal and structure all the way from St. Malo to Dinan has its counterpart. By studying the movement of the model river, the effect on the future

How Nuclear Blasts Will Dig a New Panama Canal

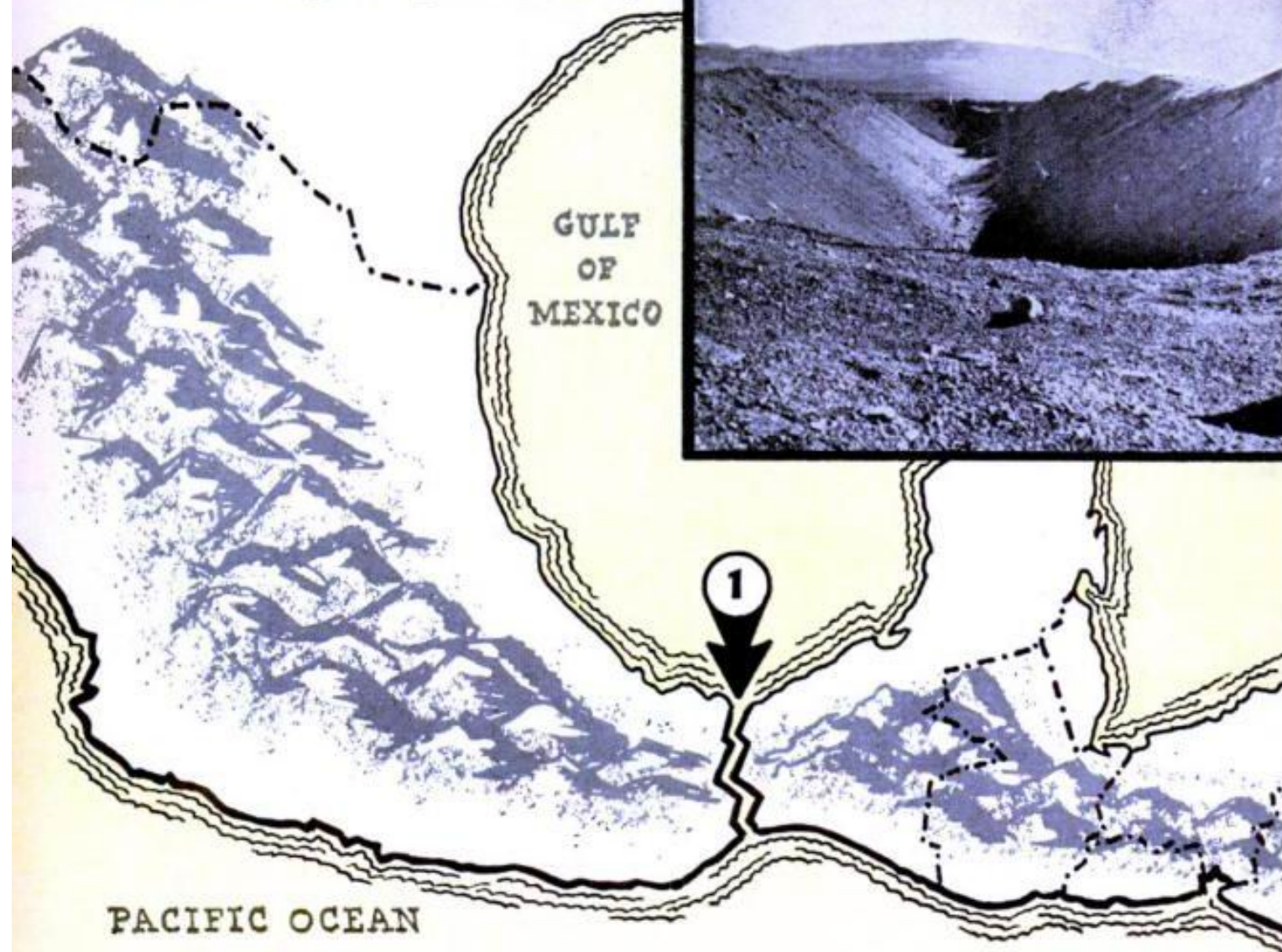
With nuclear "dynamite", a giant sea-level ditch is easy

By S. David Pursglove

FOR a quarter of a century, dreamers and hardheaded businessmen as well have been conjuring up new schemes to jockey huge ships across the aggravatingly skinny, but mountainous,



ROW CHARGE technique, tested with 13 simultaneous "nitro" charges in Nevada, produced this continuous ditch. Nuclear charges will dig new canal similarly



FIVE POSSIBLE ROUTES for a new canal have been selected from 30 alternates. They include: (1) Tehuantepec, through Mexico; (2) Greytown-Salinas Bay across Nicaragua; (3) San Blas through Panama; (4) Sasardi-Morti through Panama; (5) Atrato-Truando via Panama and Colombia. Present canal is (6). Nuclear explosives would blast canal as shown on previous page

strip of land connecting North and South America. Ambitious promoters have proposed tunnels through the alpine backbone of the Isthmus, lake chains connected by man made rivers and—wildest of all—a king size railroad on which ships would ride piggyback from ocean to ocean.

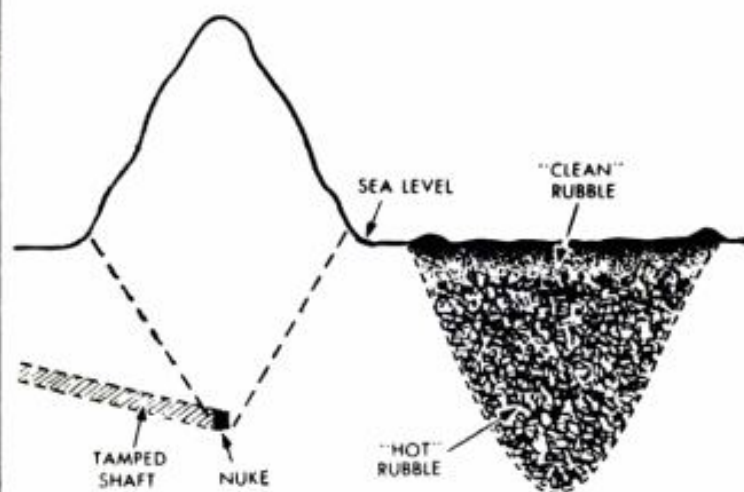
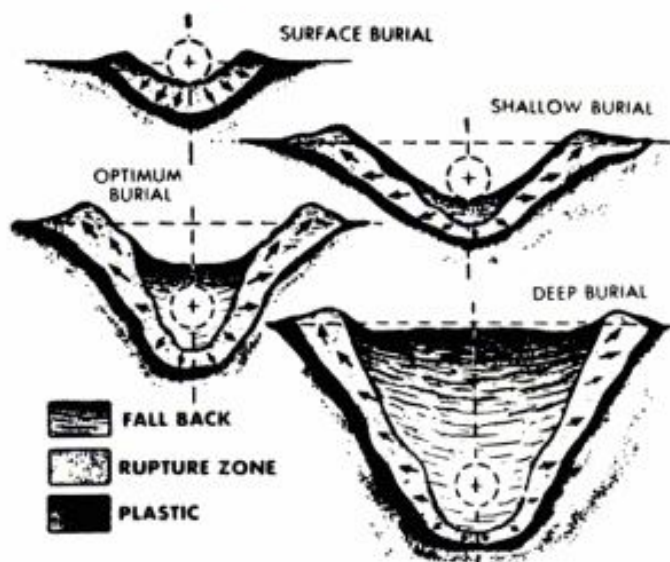
But the fondest dream of all has been a colossal sea-level ditch. Today, that idea is no longer a dream. It may happen—and soon. It can be done without squadrons of earth-moving monsters—at one-third the cost they would involve—and will result in an ocean-to-ocean river four times wider and twice as deep as the present canal; a "ditch" big enough to take the world's largest tankers and carriers—

something the present canal won't do.

The question is no longer "Can it be done?" It is "Where, how and when can we dig it?" Scientists and engineers working with the U.S. Government's Panama Canal Company, the Atomic Energy Commission and the Army's Corps of Engineers already have most of the answers.

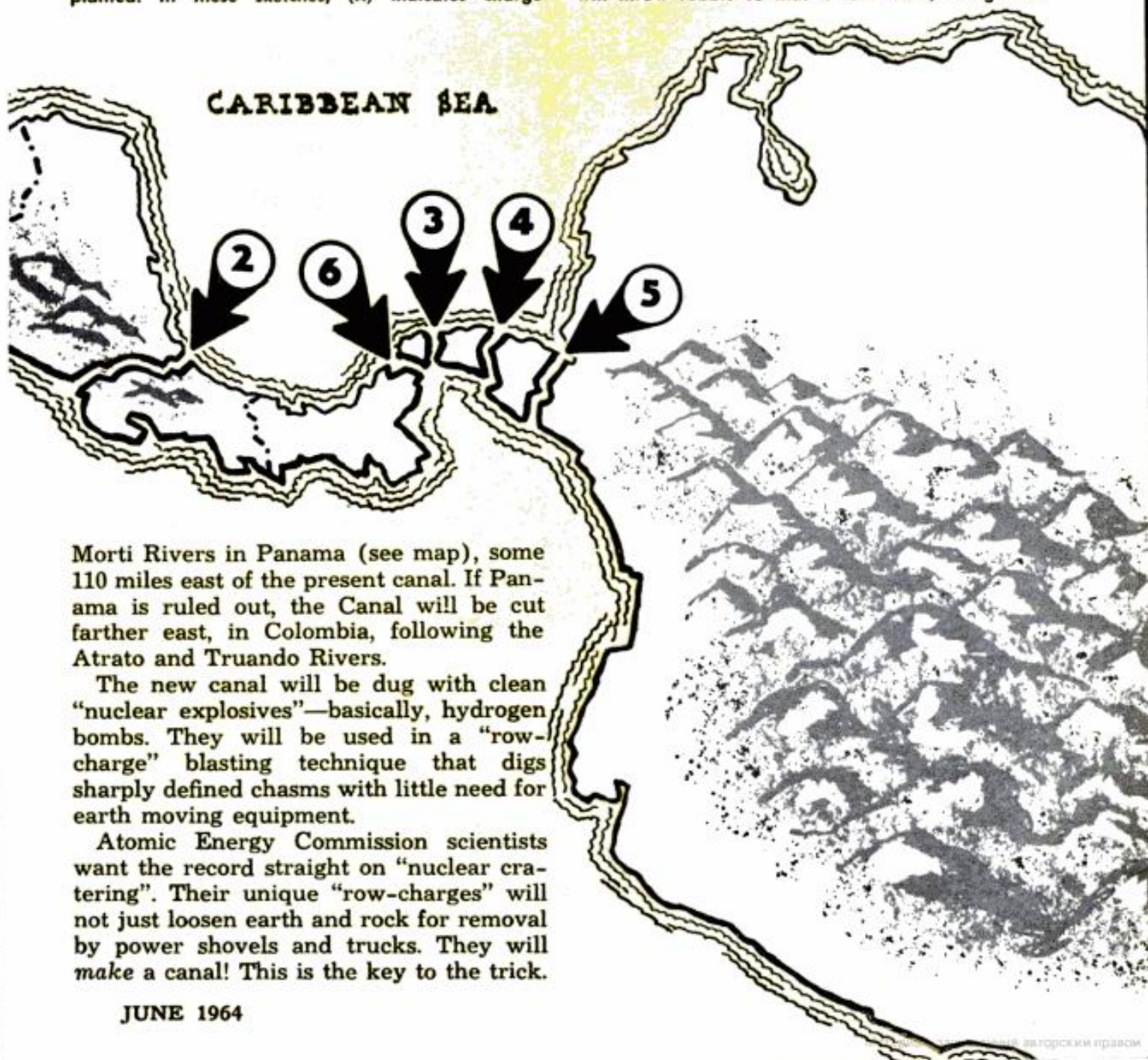
Where? Near the Panama-Colombia border. How? By means of thermonuclear excavation based on new techniques. When? Within five or six years. These decisions are firm. All that remains to clear the way for the first blast is the necessary diplomacy and official approval.

The best route, from an engineering standpoint, lies along the Sasardi and



CRATER PROFILES show how shape of ditch can be determined by depth at which explosive charge is planted. In these sketches, (X) indicates charge

SINGLE CHARGE, if buried deeply enough, as shown above, will not only level an entire mountain, but will throw rubble so that it falls back, filling ditch



Morti Rivers in Panama (see map), some 110 miles east of the present canal. If Panama is ruled out, the Canal will be cut farther east, in Colombia, following the Atrato and Truando Rivers.

The new canal will be dug with clean "nuclear explosives"—basically, hydrogen bombs. They will be used in a "row-charge" blasting technique that digs sharply defined chasms with little need for earth moving equipment.

Atomic Energy Commission scientists want the record straight on "nuclear cratering". Their unique "row-charges" will not just loosen earth and rock for removal by power shovels and trucks. They will make a canal! This is the key to the trick.



GIANT BLISTER, 800 feet wide and 290 feet high was phenomenon produced by 100 kiloton Sedan "bomb", buried deep underground. When the bubble burst . . .



. . . it revealed a crater measuring almost a quarter of a mile wide and 320 feet deep. Some 7.5 million cubic yards of earth had disappeared completely



"CLEAN" BOMB produced such low radiation levels that scientists in everyday clothing entered the Sedan crater on a cable only six months after blast

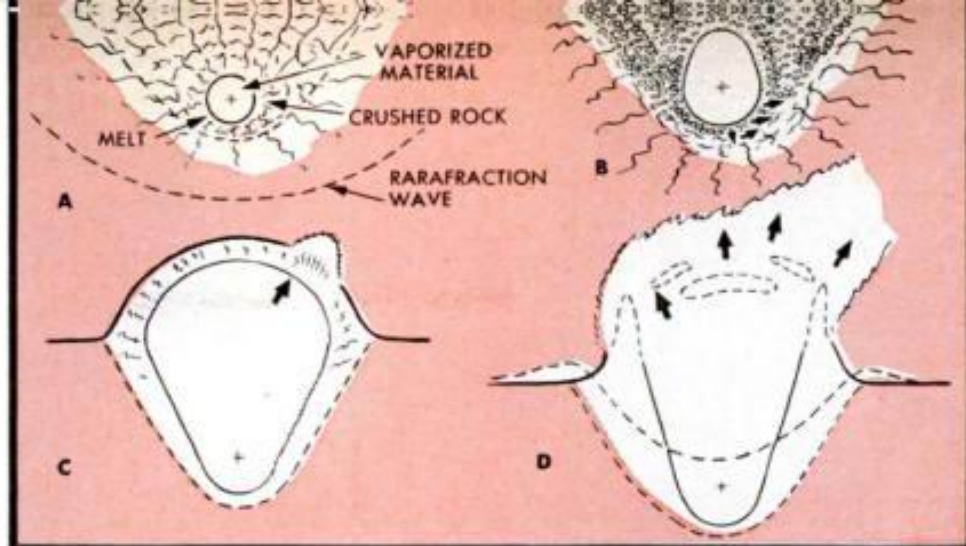
The A.E.C. developed the method in a series of Nevada tests. Eight more blasts, spread over four years, will be sufficient to refine the system.

Actually, some 30 routes across Central America were studied by the Canal Company. These were narrowed to five by the A.E.C. Next step: to survey and core-drill the Sasardi-Morti and the Atrato-Truando routes. If one of them meets international and geophysical requirements, A.E.C. Chairman Dr. Glenn T. Seaborg insists digging can begin five or six years later.

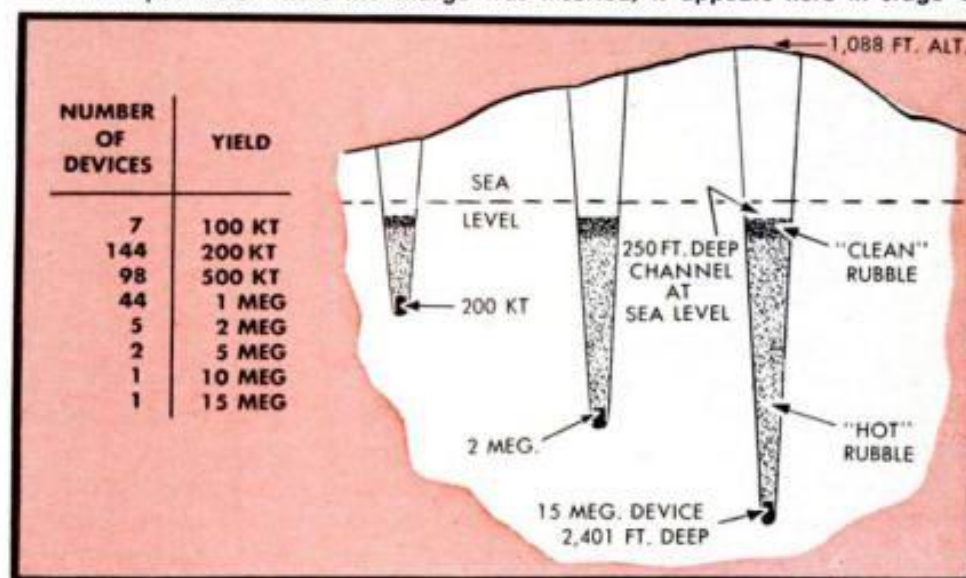
Real secret of the new technique is called diffusion blasting, first developed with conventional explosives and more recently applied to nuclear devices. Engineers have worked out formulas that tell them what size of charge to use, and how deep to bury it in order to blast out a par-

ticular size and shape of hole. They can produce ready-made railway cuts, steep-walled craters, or even remove mountains. They can so arrange their blast that the debris will fall into a gorge and form a precisely located dam of specific dimensions.

A dozen years ago, in a series of Nevada tests with way-out names like "Buster Jangle-U", "Teapot ESS", "Neptune" and "Danny Boy", A.E.C. learned what happens when nuclear explosives are detonated at various depths in the earth. In 1951, "Buster", yielding 1.2 kilotons, or the force of 1200 tons of TNT, was set off 17 feet below the surface. It dug a crater 53 feet deep and 258 feet across. "Teapot", tamped in a 67-foot hole, formed a crater 294 feet in diameter and 90 feet deep. "Neptune", a 1/10th-kiloton bomb, was buried 100 feet deep and formed a shallow



BUBBLE DEVELOPMENT in an underground nuclear blast progresses as shown in sketches above in this four-stage alphabetical sequence. Blow occurs via the tamped hole where the charge was inserted; it appears here in stage C



SASARDI-MORTI canal route would call for 302 nuclear devices with a total yield of 170 megatons equal to 170 million tons of TNT. To cut a sea level ditch in simultaneous explosion, bomb depths would vary as shown here

crater. "Danny Boy", a tiny 0.4-kiloton "firecracker" blew a precisely predicted crater in hard rock—proving to physicists that their formulas applied to many types of excavation material.

After more tests with nuclear as well as chemical explosives, scientists began to nail down a basic cratering theory. It says in part that the deeper the charge, the wider and deeper the crater—up to a point. After that, debris flies straight up and down, re-filling the hole.

Following this series came "Sedan", first whopper in the Plowshare program aimed at testing newer, cleaner nuclear explosives for peacetime uses. Sedan had a yield of 100 kilotons, equal to 100,000 tons of TNT. With five times more oomph than World War II atom bombs, it proved itself a mighty tool for earth moving. The charge

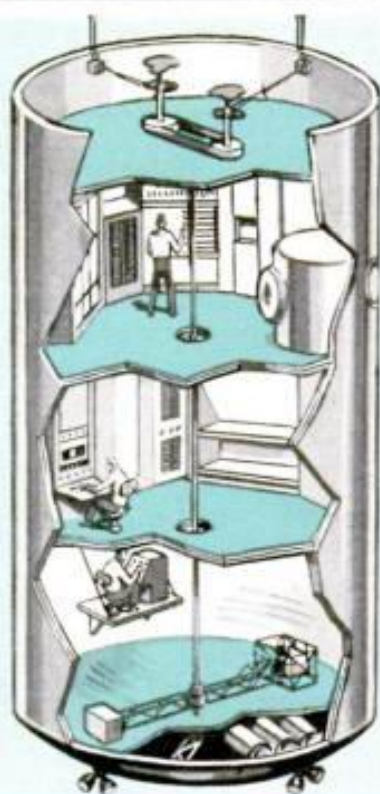
itself was packed in a cylindrical canister eight feet long and 34 inches in diameter, which engineers lowered down a 635-foot shaft in soft Nevada soil. Early in July, 1962, they pushed the button. Observers watched, fascinated, as the earth trembled. The desert floor surged upward in a huge blister 800 feet across and 300 feet high—then blossomed. Fiery gases burst from it; a mushroom cloud soared skyward; earth and rock shot 2000 feet into the air. When the dust settled, scientists found themselves staring at a perfectly formed crater 320 feet deep and a quarter of a mile across. In a single, mighty whoosh, some 7,500,000 cubic yards of matter vanished.

As a result of this success, Sedan-type bombs—and bigger—are now being scaled down to 12-inch diameter for canal digging and other giant earth moving jobs.

Will We Pass Up the

MARS excursion module sits atop basic nuclear-powered spacecraft, shown in earth orbit prior to rendezvous with Saturn V boosters carrying propellant tanks. See pages 106-107 for rest of Mars journey sequence

A SPACE LABORATORY, probably the Langley "Can," will soon be orbited to conduct the life-support experiments essential for a 19-month Mars journey. Lower compartment has a centrifuge for gravity experiments; prolonged weightlessness may make production of artificial gravity a necessity



Moon for Mars?

Orbiting laboratories, soon to be sent aloft, could shorten the lead time necessary for our first space journey, whether the destination is the moon or Mars

By S. David Pursglove

WHAT WILL AMERICA do next in space?

Is the moon a *must* as a first step, or will we leapfrog that satellite and head for other orbs?

Mars? The red planet is already scheduled for the '70s. But first, we have to find out how to make that 14 to 19-month trip—something that the seven-day moon trip will not tell us. Whether or not Americans ever blast off for the moon, the U. S. has already started its attack on the problem of finding a way to Mars.

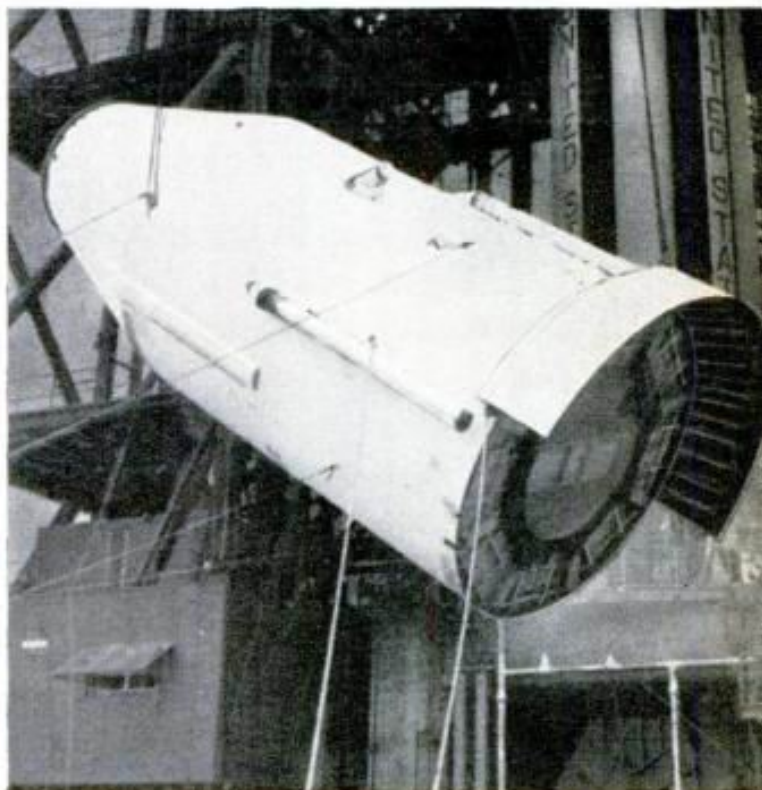
We will seek the solution by orbiting an unglamorous, not very large and not even very expensive metal

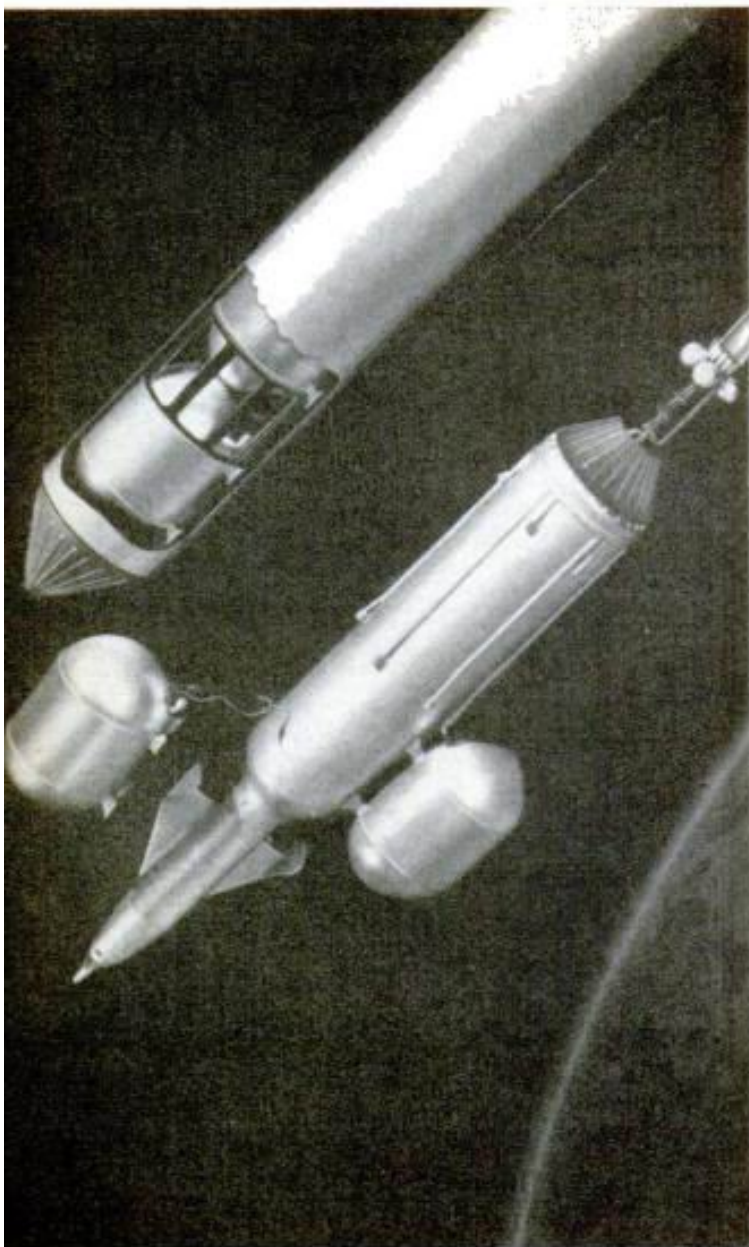
can. As soon as it is firmly in orbit, four astronauts will board a "space ferry" and be hurled some 200 miles from earth to a rendezvous with the can. There they will clamber into the cramped metal cylinder that a few irreverent space-agency officials already are calling "that oversize G.I. can."

Hurting at 17,500 m.p.h., more than 200 miles from the earth, the astronauts will experiment and study for at least 100 days, probably for four months and perhaps six months. They will live in the orbiting space station at least 75 times as long as Gordon Cooper was in Faith 7. They

MODELS of a two-stage Saturn with Apollo spacecraft are undergoing exhaustive wind-buffeting tests at the Langley Research Center's Transonic Tunnel

SECOND STAGE of the gigantic Saturn IV booster being hoisted up gantry for testing. It will carry the Apollo capsule to the moon, may orbit the space lab

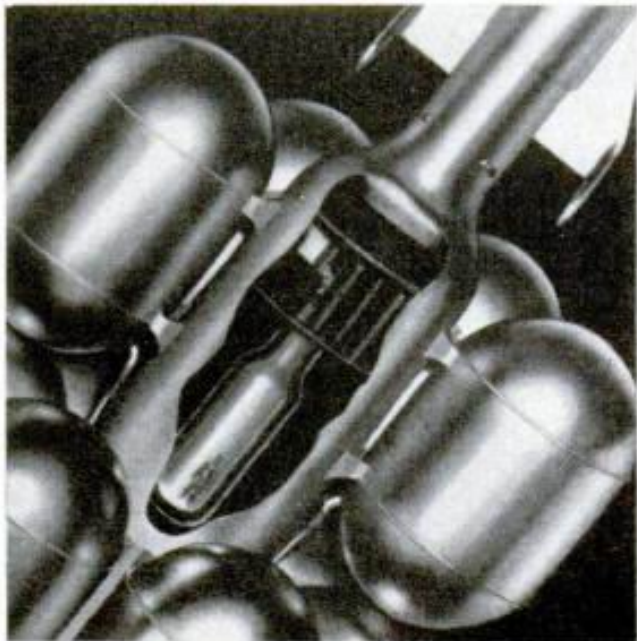




will try to exist without the comforting and perhaps essential effects of gravity, brave radiation hazards and risk puncture of the "can" by meteoroids some 40 times as long as Valery Bykovsky and Valentina Tereshkova orbited during their heavenly duet earlier this year.

In the orbiting laboratory, the astronauts will be able to study the mysteries and dangers of living in space more than 15 times as long as would be experienced by astronauts in an Apollo moon-trip capsule. This is the important reason for the proposed manned orbiting space station, or laboratory.

What will happen to a man living with-

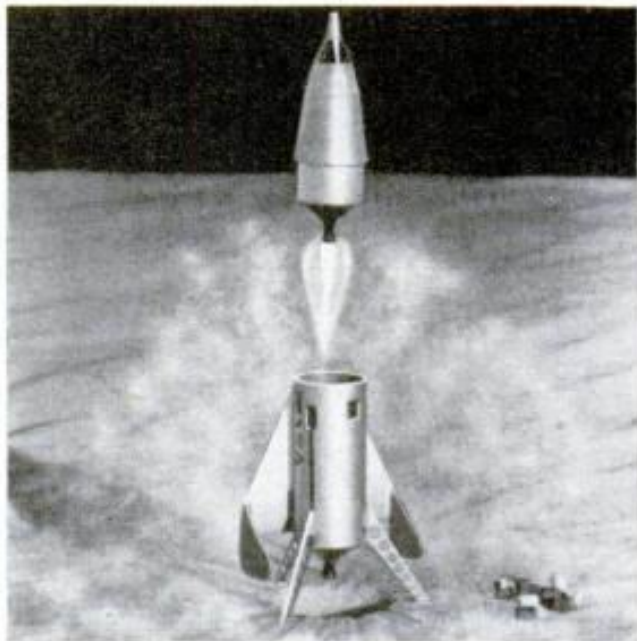
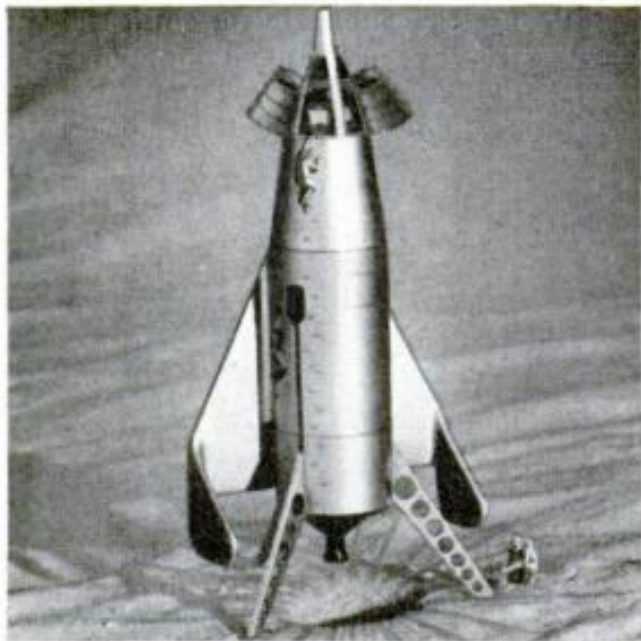


1. THREE BOOSTERS will hoist 12 hydrogen tanks which will be attached to Mars craft by the crew

2. CREW QUARTERS are back of landing module; "storm cellar" capsule protects from solar flares

5. TWO of spacecraft's four-man crew will ride the landing module to Martian surface for five-day stay

6. FIRST STAGE of module, which will be left on Mars, will be launching platform for the escape capsule



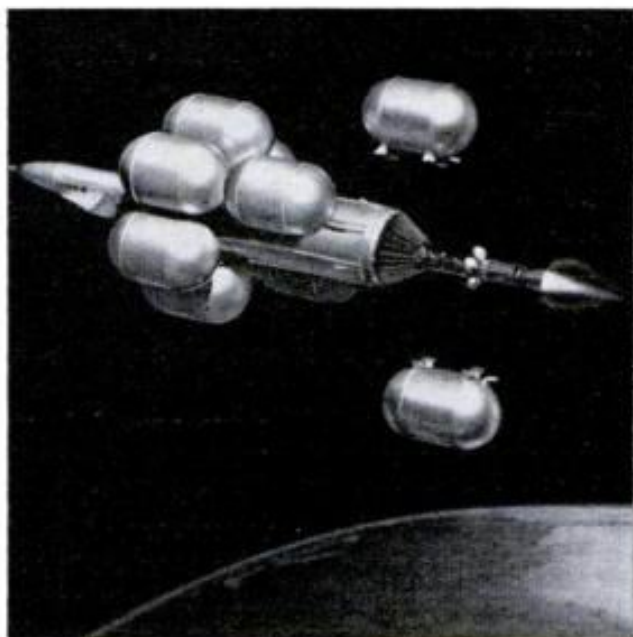
out gravity, and perhaps *with* radiation, on a 400-day—or longer—Mars trip?

Will blood, flowing unevenly under prolonged weightlessness, permanently damage a Mars voyager's brain? Will his blood gradually try to settle in pools and fail to circulate properly? Will calcium separate from his bones in the absence of gravity and slowly shift to body organs where it does not belong? Some researchers think so, based on short-term partial simulation of weightlessness in water tanks, and observation of long-time bed-ridden patients.

If life in the orbiting laboratory bears out these fears, then the spacecraft that

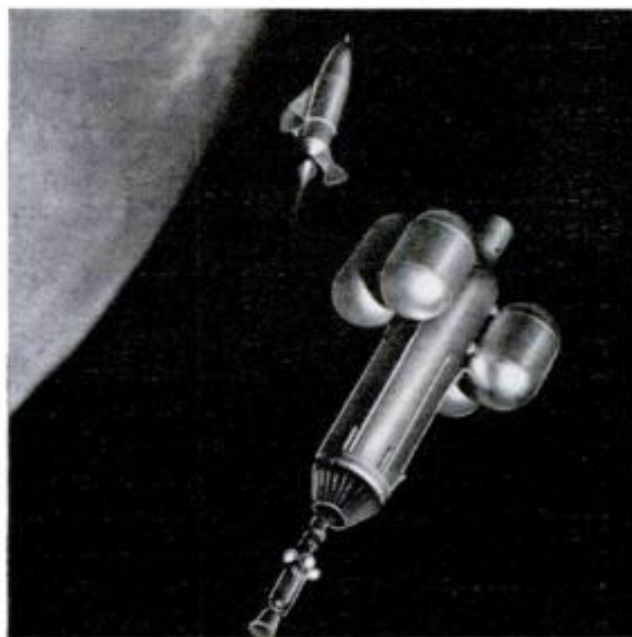
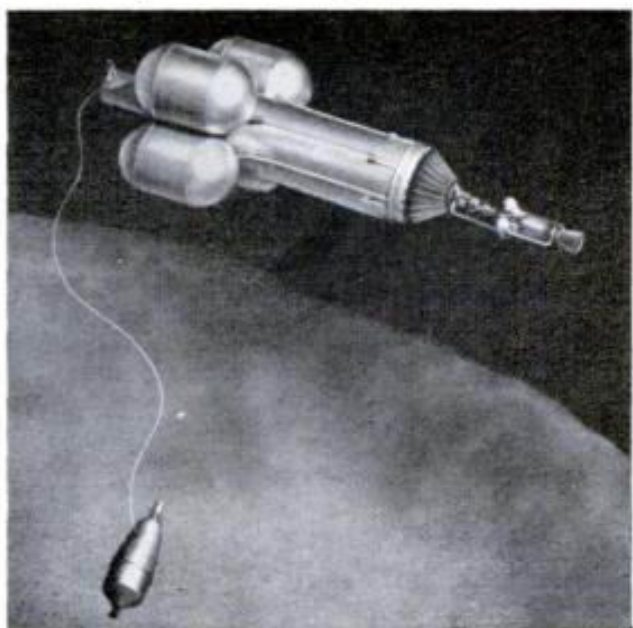
National Aeronautics and Space Administration engineers will design for the Mars adventure will have to have built-in gravity. Many scientists are convinced that a Mars craft will have to have at least *some* artificial gravity. Hopefully little, because the greater the gravity effect that must be created, the greater the expense, engineering problems and the chance that something might go wrong.

Artificial gravity is produced by spinning the chamber where the men live and work. Centrifugal force directs body weight outward and gives a man's feet a substantial platform on the outer wall of a round chamber. It seems "down" to him. It will



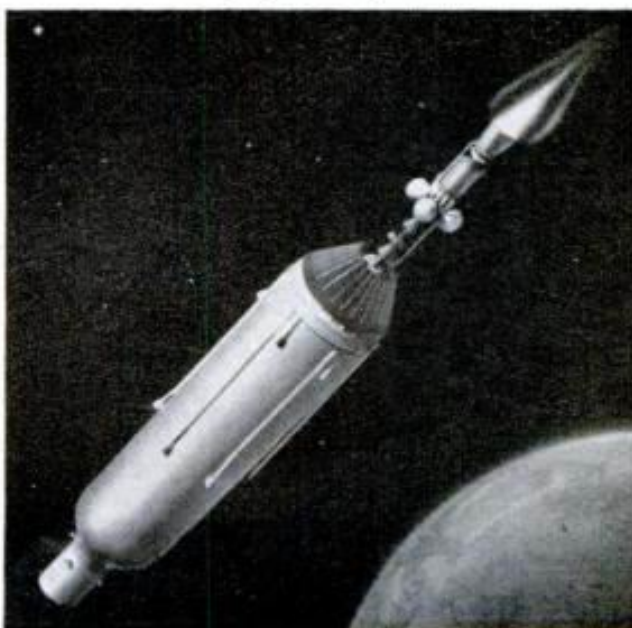
3. SIX FUEL TANKS will power earth escape; two empties are retained in case of meteoroid puncture

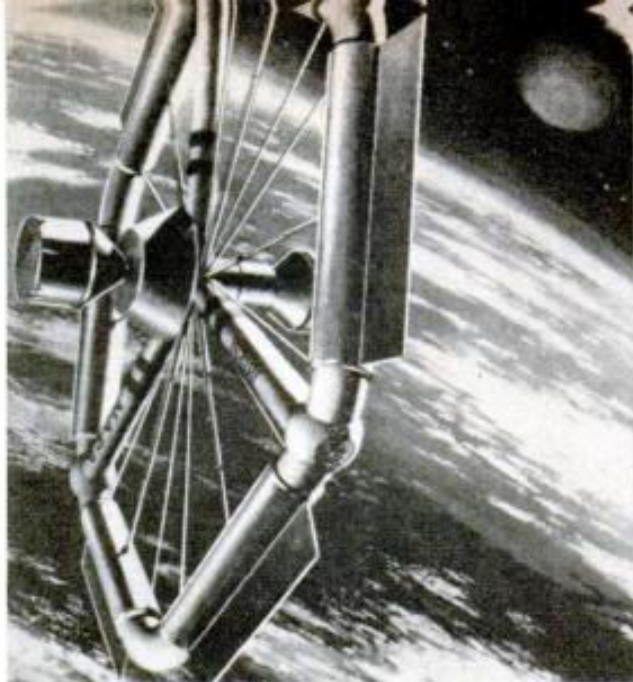
7. CAPSULE will be abandoned in Martian orbit once crew has rejoined mother ship for the return to earth



4. LANDING MODULE leaves spaceship in Mars orbit. Rockets and drag slow it for landing on planet

8. ALL FUEL TANKS will be jettisoned when rocket re-enters earth orbit; space ferry will land the crew





HEXAGONAL SPACE LABS of the future will rotate to provide artificial gravity for crew. The center is stationary (in effect) for studies of weightlessness



EARLY DESIGN for inflatable manned space station, the "innertube," was scrapped when rapid development of big boosters made better stations possible

also seem "down" to his blood, bones and his bladder as well.

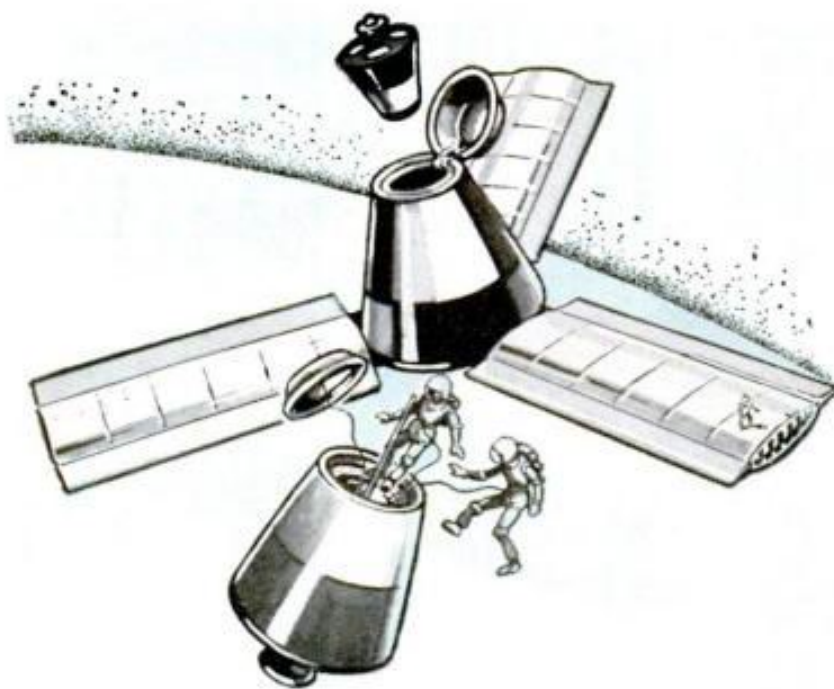
Slow rotation of a small space chamber would produce *some* gravity effect. Fast spinning would result in a much greater effect, but then the crew would suffer dizziness. In large, slowly turning units wobble becomes a real problem. Slight shifts in weight—such as men walking—must be countered with automatically moved weights or heavy mercury piped continuously to where it is needed by computer-controlled pumps.

Design, cost and reliability all suggest using the smallest amount of artificial

gravity that will do the job. So, one major task for the first space station crew, three or four years from now, will be to find out just how little artificial gravity is needed to keep men healthy and alert on the long flight to Mars.

Does this sound like we are giving up the moon race and putting our prestige bets on a trip to Mars first? Washington has been rife with such rumors. A newer rumor that seems to make the most sense, however, is heard at nearly every turn nowadays. It contends that we can fly around Mars and return, without landing,

[\(Please turn to page 230\)](#)



Y-SHAPED second-generation space lab probably will follow the Langley "Can" into orbit by the mid-1970s. Designed by Manned Spacecraft Center in Houston, it will hold a crew of 36, will be hurled into orbit by Saturn V. Enlarged Gemini or modified Apollo capsules will ferry crew and supplies to and from earth. Compartmented arms will rotate about the central chamber to create artificial gravity. The central chamber will be used for experiments in weightlessness

Sub Rescues-Four Miles Deep

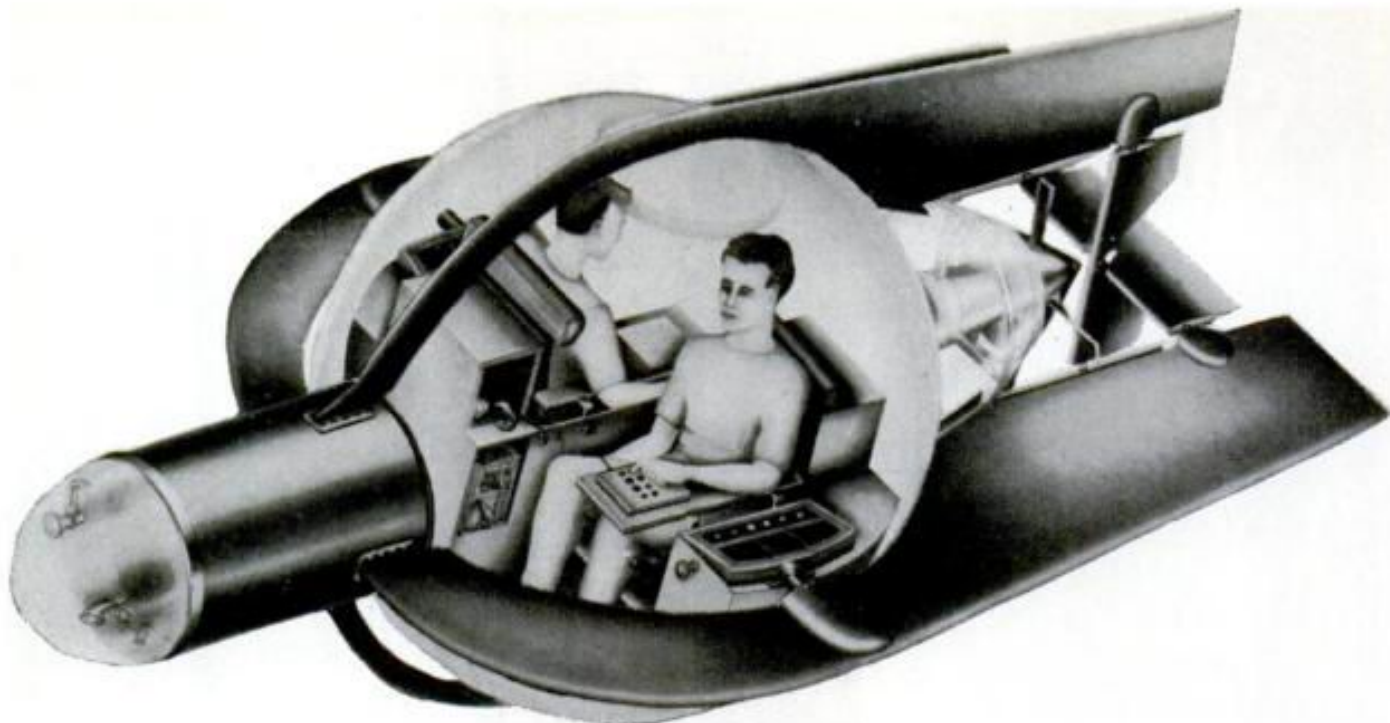
Stunned by the Thresher disaster, the Navy is rushing to develop a family of buglike vessels that will snatch men from death under the sea



By S. David Pursglove

OVER THE NEXT FIVE YEARS, the U.S. Navy will build a fleet of the weirdest looking vessels ever imagined. Experimental models of eerie, crablike metal and plastic monsters are even now far beyond the drawing board stage. They are as unlike conventional surface vessels as space craft are unlike ordinary aircraft.

Their mission will be to probe the abysses of the deepest ocean floors. And they will attempt to answer two of the Navy's toughest problems: How to rescue men from a stricken submarine beyond present rescue range of 1300 feet *and* how to raise a crippled sub from



PLEXIGLASS SPHERES for deep-diving research submarines are now undergoing tests by Naval Ordnance. They would give full visibility down to 2000 feet

any depth, especially if it carries Polaris nuclear warheads. Future subs are expected to operate below 20,000 feet.

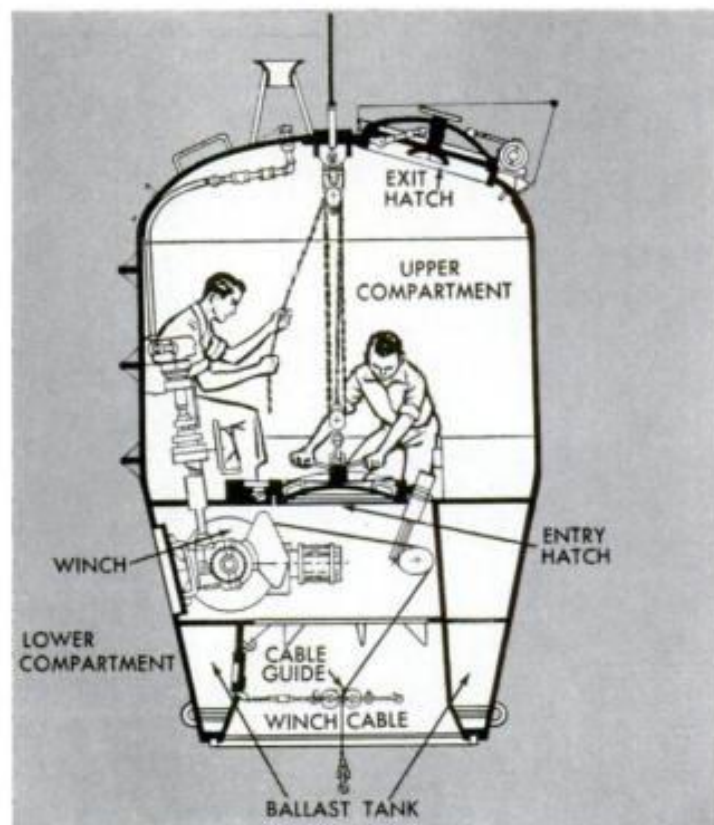
It took the USS *Thresher's* 129 officers, enlisted men and civilians lying dead on the Atlantic floor to jolt the Navy into resuming research on the art of rescuing sub-

marine crews and salvaging sunken hulls.

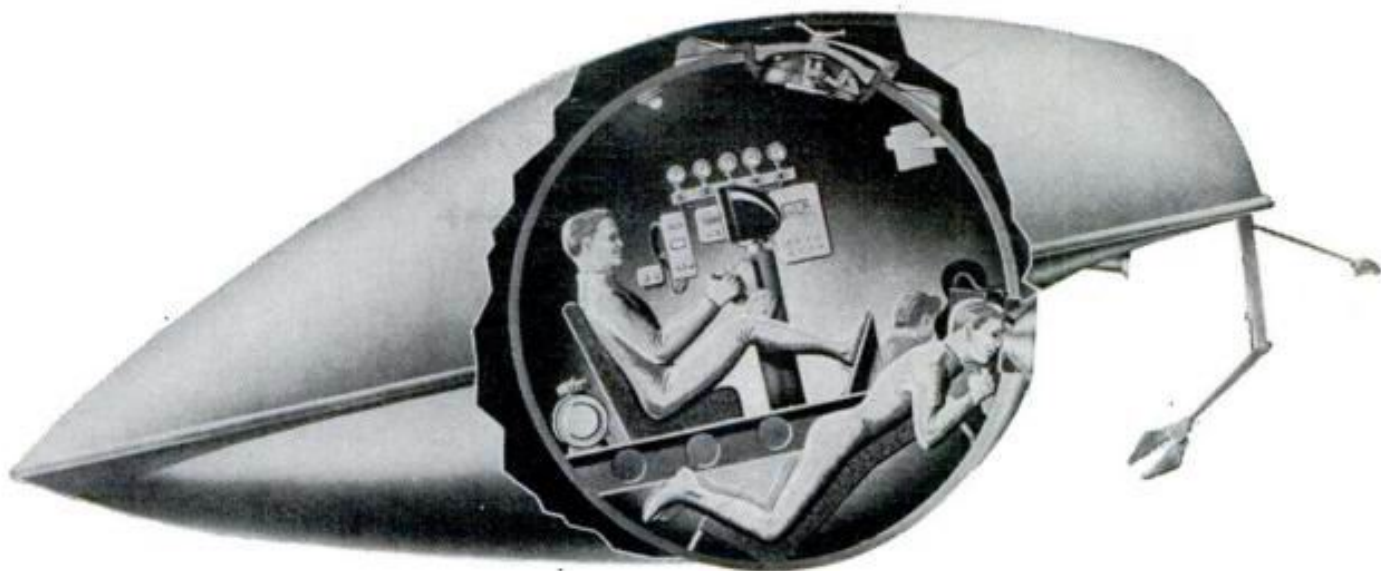
Two weeks after the *Thresher* disappeared in 8400 feet of water, Navy Secretary Fred Korth ordered Rear Adm. Edward C. Stephan, the Navy's chief oceanographer, to form a committee to look at America's present sub rescue and

STEINKE HOOD permits submariners to breathe while popping rapidly to the surface in a "blow and go" escape; it also blocks cold water from their eardrums

McCANN RESCUE CHAMBER, which will hold nine men and two operators in its upper compartment, is winched down to a disabled sub's escape hatch



POPULAR MECHANICS



DEEPSTAR, a three-man craft for maneuvering at 12,000 feet, is now being completed by Westinghouse. Pilot guides it by means of three echo sounders

salvage ability and its plans for the future.

What the Stephan committee learned about our present capabilities was discouraging. Most rescue equipment dated to well before World War II. No attempt had been made to salvage a sunken sub since the USS *Squalus* went down in 1939. In fact, the Navy formally gave up sub salvage as too costly in the early 1950s when much salvage gear was removed from sub-rescue ships.

Only one major piece of personal rescue equipment, a simple but effective hood, had been introduced since the 'thirties. The McCann Rescue Chamber had been strengthened for slightly deeper operation, but it was basically the same diving chamber developed two years after the sinking of the *S-4* in 1927.

While submarines were costing \$50,000,-000 to build, total funds for submarine-rescue research had been averaging only \$25,000 a year, about the salary of one good space-flight scientist in industry. (The Space Agency and Air Force have spent several millions to explore techniques for rescuing men from stranded space vehicles which haven't even been built yet.)

On the positive side, the Stephan committee found Navy divers working long hours and taking unbelievable risks to push salvage diving capabilities slowly deeper. But at best, divers can only work a short time at 380 feet. Other rescue teams are advancing the techniques for swim-

ming away from crippled submarines, but nature is limiting their efforts to depths of only 450 feet.

But the committee found other branches of the Navy planning to live and fight routinely many *thousands* of feet under the sea. The Navy not only wants fighting craft able to maneuver at great depths; it also wants working vessels for deep-ocean study. One mission for such craft is to find locations on the continental shelf that will support some twenty-first century underwater structures that the Navy wants to build *now*.

Some of these deep-sea installations will be manned listening posts for a worldwide ASW (antisubmarine warfare) network. Others will be secret underwater arsenals for refueling and rearming Polaris-firing submarines.

The Stephan committee was told to lay out a five-year plan for building equipment and developing techniques for rescue and salvage of almost any object from almost any depth. That plan, at least in rough draft, is due in the Pentagon this fall so it can be cranked into next year's research and construction budget.

It will almost certainly call for the creation of a vast underwater double-duty fleet. That fleet will be ready at a moment's notice to rescue men from, or salvage, sunken submarines. In the interim, it will conduct oceanographic research, explore the ocean depths or undertake such

chores as retrieving missiles and nose cones from space craft.

Present diving capabilities of our nuclear subs are still classified information. Nobody knows at what depth the *Thresher* was crushed by underwater pressure. Her sister ship, the new USS *Jack*, will dive deeper than any other submarine in the world, according to the Navy. But it's safe to say that it won't go anywhere near the depths planned for the next generation of submarines. These, says the Navy, will lurk 20,000 feet beneath the surface.

The U.S. has never built any kind of vessel that could reach a crippled sub at 20,000 feet. The European-built bathyscaph *Trieste*, now owned by the U.S., has been to 35,800 feet. But *Trieste* can only descend and look. It cannot rescue men, nor can it salvage a submarine. It has been called a "good deep-sea yo-yo." Once down it can maneuver very little, and it cannot oper-

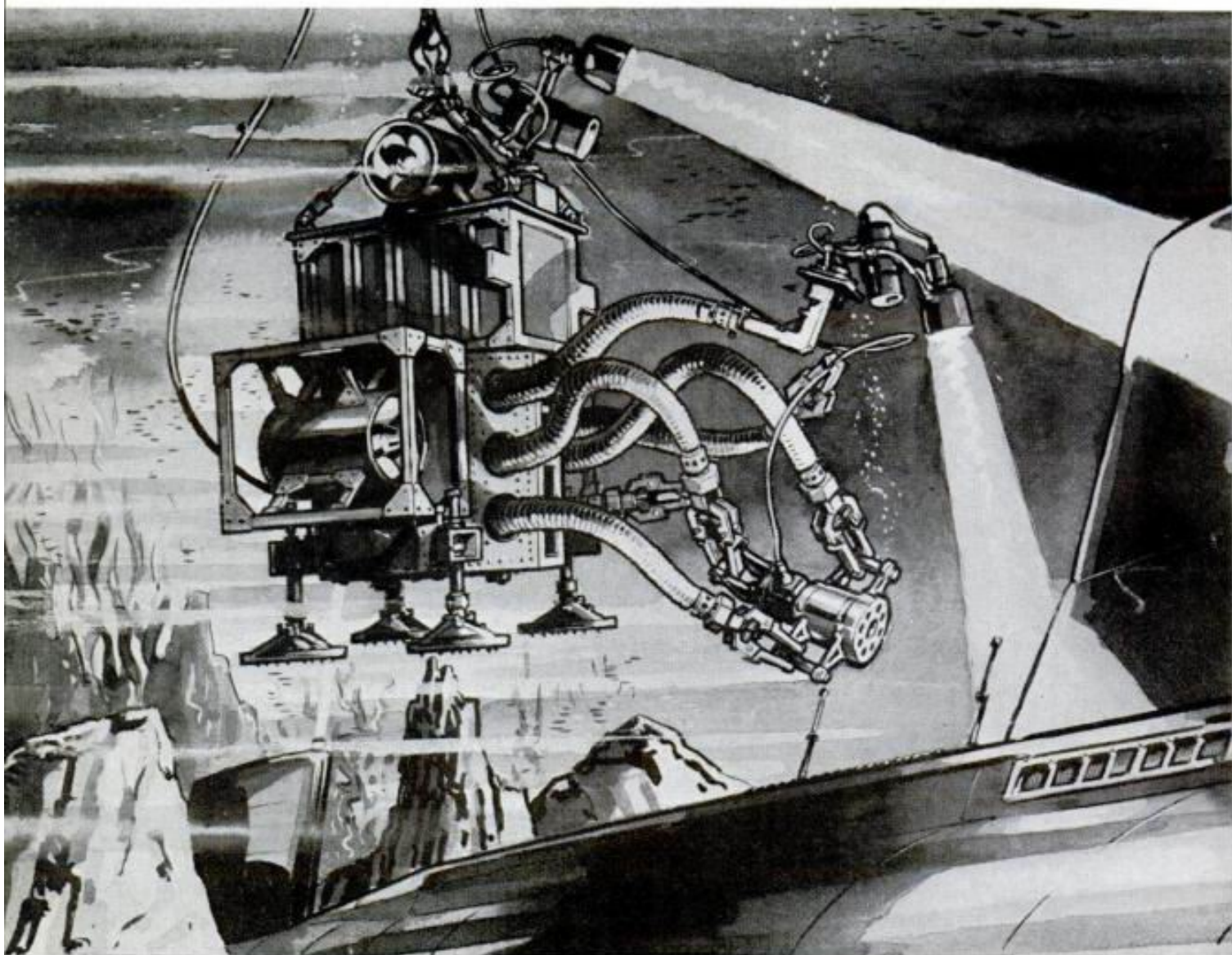
ate effectively in a current of more than one mile per hour.

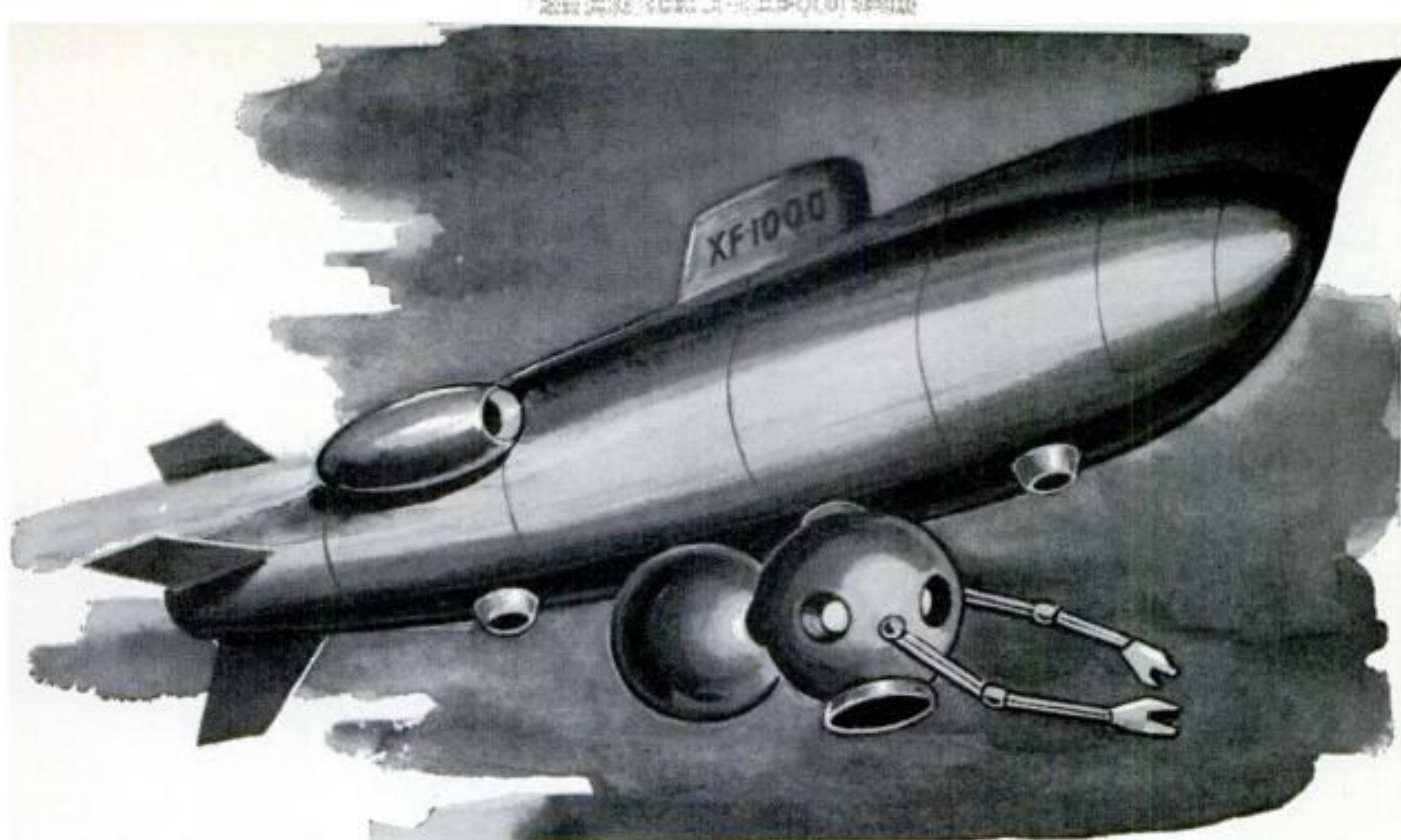
Mare Island Naval Shipyard is now putting the finishing touches on a new bathyscaph float that will have a two-to-three-mile lateral range on the ocean floor. A two-man sphere will have a four-inch diameter viewing port, and it will also transmit TV pictures to the surface. Two mechanical arms will be able to pick up objects from the ocean floor and deposit them in an outboard basket. For shallow and intermediate depths it will use a lightweight chamber, but for deep-sea areas it will use the six-inch-thick steel sphere cut from the *Trieste*.

But even this 'scaph will not have a rescue capability. That will have to wait until a deep-diving rescue vehicle now being studied by the Navy comes off the ways. This craft will be a cross between

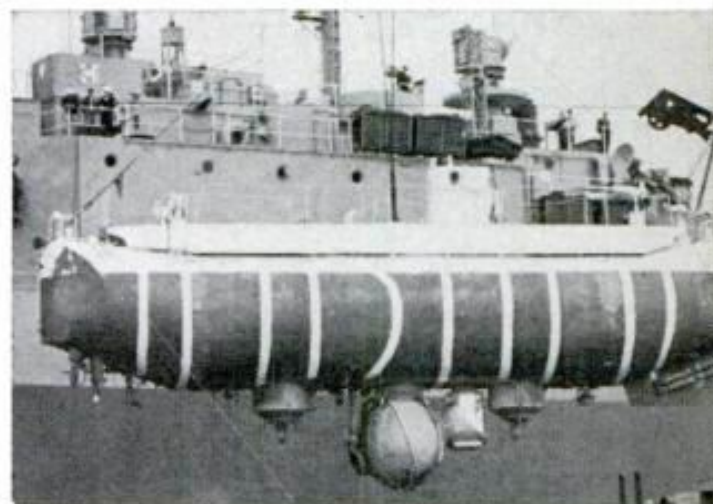
[\(Please turn to page 202\)](#)

MOBOT V, the undersea oil-well robot, could probably be used in sub-rescue work. It is surface-controlled, has motorized arms, is fairly maneuverable





PROPOSED DEEP-SEA RESCUE vessel is similar to *Trieste* but more useful. It has mechanical arms for attaching salvage cables, a sphere for personnel



THE TRIESTE can only descend and look; it can't rescue men or salvage a sunken submarine. Built in Europe but owned by the U.S. Navy, it has been down to 35,800 feet

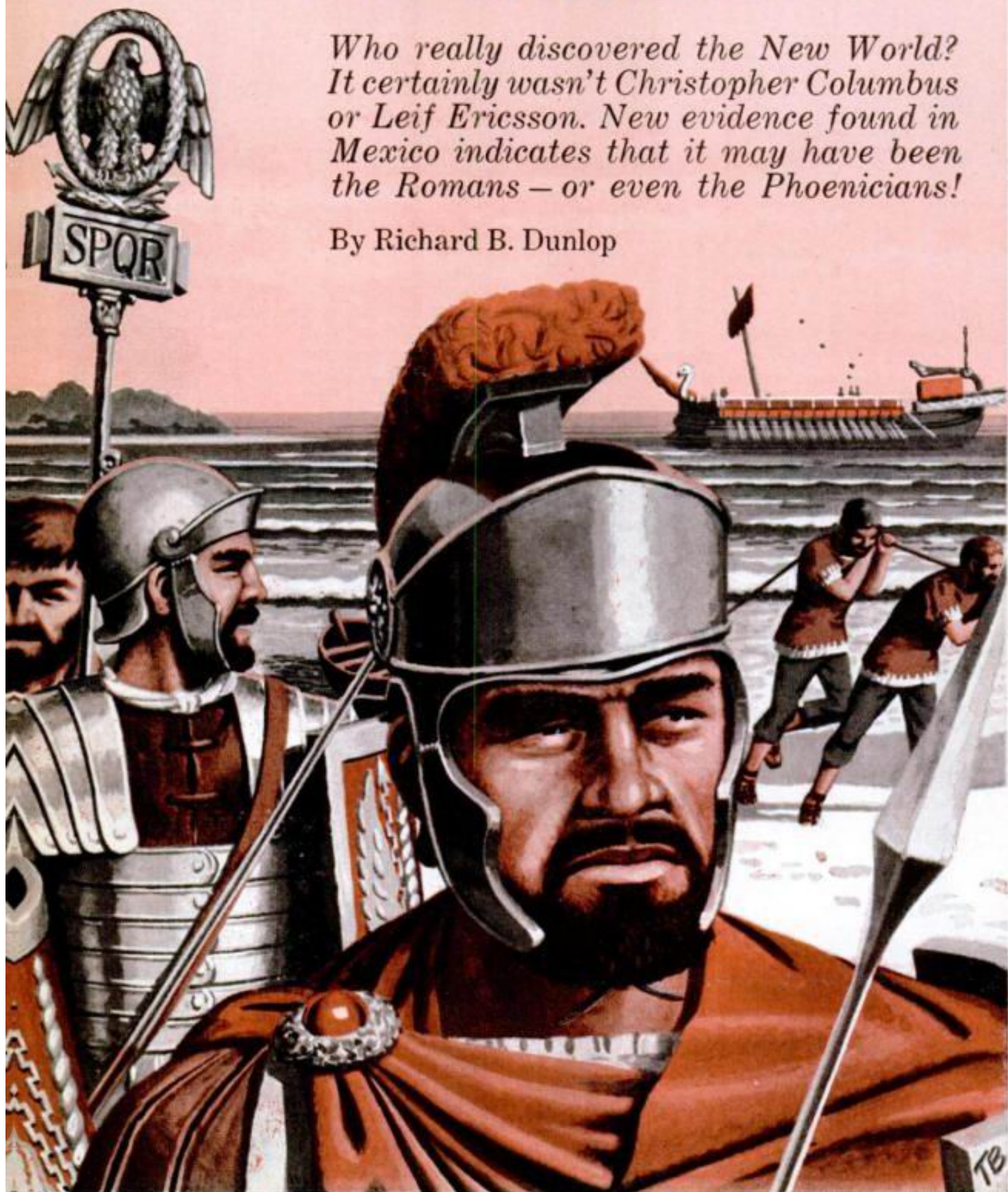
SUB-RESCUE SHIP, the *Florikan* (ASR 9), has a McCann Rescue Chamber near the stern and positioning buoys amidships; these are anchored around sunken submarines



Did the Romans Discover America?

Who really discovered the New World? It certainly wasn't Christopher Columbus or Leif Ericsson. New evidence found in Mexico indicates that it may have been the Romans — or even the Phoenicians!

By Richard B. Dunlop





SMALL CLAY HEAD "of odd physiognomy" is one of the best-authenticated indications that Europeans visited America centuries before Columbus. It was dug up at a "controlled" archaeological site in the valley of Toluca, west of Mexico City. Experts say it is a Roman head of the Second Century A.D.

IT WAS A TENSE MOMENT. The archaeologist had carefully dug through three floors of ancient stone and cement. Beneath the third floor he found two graves, undisturbed for centuries.

Buried in the graves were several items of ceramics and jewelry including, as the archaeologist wrote later, "a small clay head of odd physiognomy." For several years the archaeologist kept the head. Then, in 1959, Dr. Robert Heine-Geldern of the University of Vienna, one of the world's foremost archaeologists, visited him and took photographs of the head. Later, from Vienna, he requested that the head be sent to him.

Dr. Heine-Geldern subsequently wrote from Vienna: "I showed the small head to Professor Boehringer, President of the German Institute of Archaeology . . . and he confirmed my thesis, that is, that the small head is Roman and corresponds to the year 200 A.D."

It was perhaps the most noteworthy archaeological find in years. For the little Roman head had been found by Dr. Jose Garcia Payon in a previously undisturbed grave which dated back at least to 1100

A.D. And that grave was not in the Old World of Asia, Africa or Europe, but in a high valley west of Mexico City.

Dr. Garcia Payon, archaeologist of the University of Jalapa, had found what appeared to be the first authenticated Roman artifact in the New World unearthed in a scientifically controlled site.

Somehow, between its manufacture in the Roman world of the Second or Third Century A.D. and its burial in Mexico before 1100 A.D., the tiny head had crossed an ocean. It was seemingly indisputable evidence of a link between the Old World and the New, centuries before the voyages of either the Viking Leif Ericsson or Christopher Columbus.

The dramatic discovery of a Roman head in Mexico raises again the question of who *really* discovered America. Who was Quetzalcoatl, the "white god," who—long before Columbus—visited the Mayans, the Aztecs and the ancient Andeans? Could he have been a Roman or Greek, a Phoenician or Carthaginian, a Viking or an Irishman? Did he come from Wales, or Scotland or China? There is at least some indication that all of these peoples reached

the New World years before Columbus.

Some archaeologists accept the Roman head as proof that a Roman vessel either by design or error sailed to the Americas. Dr. Heine-Geldern went to Mexico and assisted Dr. Garcia Payon in establishing the Greco-Roman origins of the head. However, he does not believe the head arrived on a Roman ship. He argues that Roman traders and possibly ambassadors not only reached India, but Southeast Asia and China. He goes on to say that his own studies of various sites indicate there was extensive trade between Asia and America from 700 B.C. to 220 A.D. Enormous four-masted Chinese junks sailed from island to island through the South Seas and probably crossed the wide Pacific to visit Mexico.

Later, with the collapse of the Han Empire, the ships of such cities as Kattigara took up the profitable trade with far-away America. The little Roman head, says Heine-Geldern, may have been carried over to Mexico on one of these ancient trading ships.

There remains, according to Heine-Geldern, "the possibility of a pure accidental import across the Atlantic Ocean." A Roman ship carrying the little head enroute to Britain could have been carried off course by winds and currents to Mexico. The discovery in the 1880s of what is apparently a Greco-Roman torso of Venus on the Mexican Gulf Coast by the German anthropologist Seler may indicate that this was the fate of one or more Roman ships. The Venus is now in the Berlin Museum, but unfortunately there is no definite record of exactly where and how the torso was discovered.

In the 19th Century a hoard of several hundred Roman coins was discovered on a beach in Venezuela. Most experts believe the coins to be the collection of a Spanish colonial coin fancier, but they were found in a cash box resembling those known to be carried on Roman vessels. The coins were minted from the reign of Augustus to the Fourth Century A.D.

That the Greco-Roman world knew of the Americas is suggested by no less an authority than Plato, who lived from circa 427 to circa 347 B.C. The learned Greek wrote that far to the west of the British Isles were other islands beyond which, at the edge of the sea, stretched a great continent. In 150 B.C., the Roman historian Pausanias wrote that west of the Atlantic there was a group of islands whose inhabitants were red-skinned and whose hair was like a horse's mane.

The Roman consul, Metellus Celer, has left us an even more fascinating account. In 62 B.C. he was Roman proconsul in



PRE-COLUMBIAN visitors may also have left this head, said to be Roman, in Mexico. But details of its discovery are still in doubt
—COURTESY CHICAGO NATURAL HISTORY MUSEUM



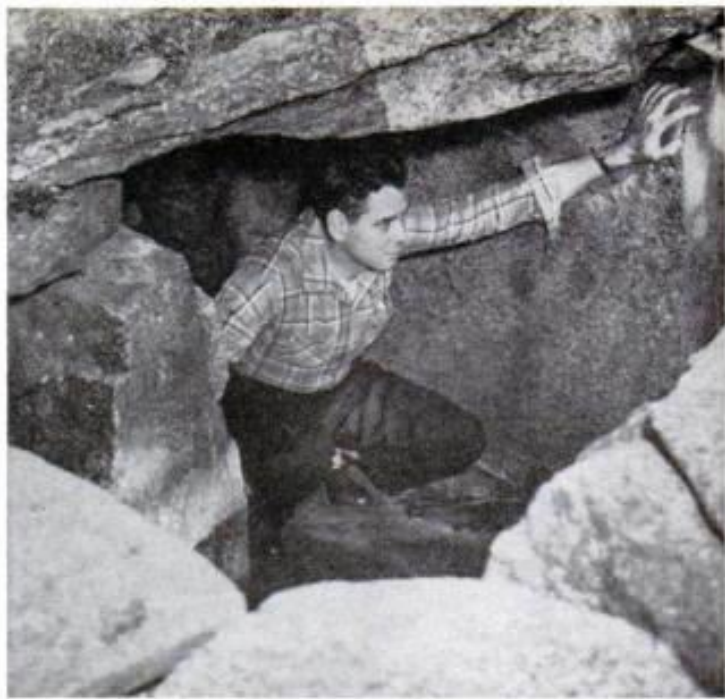
WHEELED TOY from Mexico indicates the Aztecs knew the wheel, possibly from early explorers, but failed to recognize its importance
—COURTESY AMERICAN MUSEUM OF NATURAL HISTORY



STATUES suggest the Vikings visited Mexico. Archaeologists cannot date them, however, because their discovery site was "uncontrolled"



MOORING STONES like this one at Follins Pond, Mass., are found at many Viking sites in the New World. A hole drilled in the stone held a mooring bolt



MAN-MADE CAVES, found throughout New England (this one is in North Salem, N.H.) may have been "root cellars" built by pre-Columbian Irish settlers

Gaul when the king of the neighboring Suevi brought him several strange people with red skins and black hair and presented them to him as a gift. The Roman asked where the men had come from; he was told they had been blown by high winds across the sea and cast up on the shores of Germany.

From the New World comes intriguing if controversial evidence that the Phoenicians, the great sailors of the ancient world, made it across the Atlantic. Near the little town of Gavea close by Rio de Janeiro, Brazil, there is a towering rock wall. Three thousand feet high on this cliff is an inscription long attributed by local inhabitants to the Indians.

Then Bernardo da Silva Ramos, retired industrialist, scholar and archaeologist, arrived on the scene. He inspected the curious characters and pronounced them Phoenician. Translated, the message reads, "Tyre, Phoenicia, Badezir, Firstborn of Jethbaal . . ." This inscription very possibly is more than 2000 years old because a check of ancient dynasties showed that Badezir ruled Phoenicia from 855 to 850 B.C. and was the son of Jethbaal, who ruled from 887 to 856 B.C.

The Brazilian government officially maintains that the writing is merely weird weatherings on the rocks. This position seems absurd to many anthropologists, who ask how rocks could erode to form not only Phoenician language, but also correct Phoenician history.

Moreover, the inscriptions are not the only ones found in Brazil. Ramos, in years

of searching through the Amazon jungles, discovered and copied some 2800 separate writings. He had the stones translated from Phoenician into English. Did a hoaxer risk malaria and curare-tipped arrows to scatter these marked stones? Or did, as Ramos claimed, generations of Phoenician "Kilroys" leave the record of their New World travels?

Central and North America also contain indications of Phoenician visitors. In Yucatan and other parts of Mexico, Mayan and Aztec ruins have yielded hundreds of ancient statues which depict men with the hooked noses and beards of the ancient Phoenicians.

Then, in 1948, an elderly doctor found inscribed stones near Mechanicsburg, Pa., which Cornell University experts said might be Phoenician. The stones were sent on to philologists at the University of Strasbourg in France, who said the characters show a resemblance to Carthaginian script. Carthage was a Phoenician colony. Some of the stones apparently bear the first few characters of the Phoenician alphabet: aleph, beth, gimel, daleth.

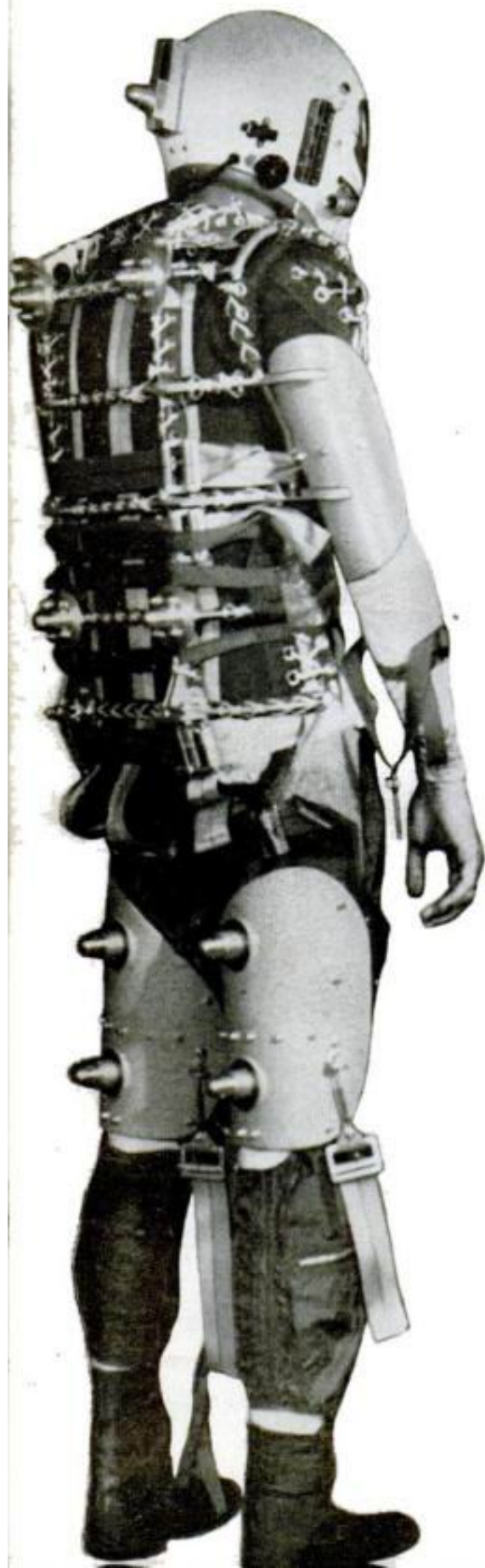
Other possible mementoes of the Phoenicians in the New World include the carving of a ship at anchor on the rocks of Lake Assawampsett, Mass. The boat's mast remains erect although the sails are lowered; this indicates a Phoenician design. Vikings lowered sails and masts both when at anchor.

Near Clarksville, Va., James V. Howe found a deposit of worked "bog" iron on

(Please turn to page 186)

Our First Moon Trip started at

By S. David Pursglove



IT BEGAN AS an Air Force bus rolled to a stop beside a concrete ramp 1500 yards inside Gate 3 of the new North Section at Cape Canaveral, Fla. Four men got out, clustered beside the bus door, and stared skyward.

Three of the coverall-clad figures showed outward signs of youth. There was a sprinkle of grey through the fourth man's close-cropped hair when he pushed back his baseball cap for a better look at the monster towering above them.

The object of their attention was a white-and-silver shaft jutting majestically 185 feet into the still-cool morning air. Four pairs of eyes followed the ever-broadening sides of the monolith downward until its base disappeared into a canvas shroud that a steel-helmeted crew was removing. As the canvas fell, four enormous funnels were revealed. Each of these nozzles could have accommodated the small group, now walking from the bus to the base of a steel skeleton that towered on equal terms with the enormous rocket.

Lt. Col. Leroy G. Cooper, Jr. (or it could be Shepard, Glenn, or any of the other current astronauts) stepped aside as the group approached a wire cage. He let the three younger men enter first. Then Cooper, now a senior instructor in the manned lunar flight program closed the cage door.

The elevator rose slowly. At 70 feet the rocket shaft tapered inward where the huge solid-propellant booster mated with the smaller second stage. A few feet farther up a coat of white frost indicated that the cage was passing the second stage's unbelievably cold tanks of liquid-hydrogen fuel and liquid-oxygen oxidizer. The frost ended 25 feet higher as the car passed a fairing connecting the

Express to the Moon—or

Recent news reports have described a NASA plan to place several rockets into orbit, then link them into a space ship while they circle the Earth. This is the so-called "rendezvous" plan. This *Popular Mechanics* article, prepared after detailed discussions with officials responsible for our manned nonflight program, depicts a single large rocket. Why this apparent conflict?

NASA is exploring *both* techniques. *PM* discussed both plans with scientists, officials and even a member of the committee charged with making the final decision. Very likely no decision will be made before 1964. However, in almost every case where *PM* asked for a "best guess," these men gave a marked edge to direct ascent, as shown here, over orbital rendezvous.

The much-ballyhooed Advanced Saturn C-5, a larger

4:30 the morning of July 1, 1969

second and third stages. Shortly, more frost appeared to indicate the third stage tanks.

The car stopped alongside a catwalk leading twenty feet across open air to the monster rocket's final stage, the Apollo space capsule. The capsule looked only slightly different from the two others that the Astronauts already had flown in preparation for their voyage to the moon.

The first, more than two years earlier, had been a cone mounted on a drum. Attached behind—or “beneath,” depending on orientation of the viewer—the control capsule and its drum had been a long, cylindrical “trailer” that was home and laboratory for the three men for two weeks in orbit around the Earth.

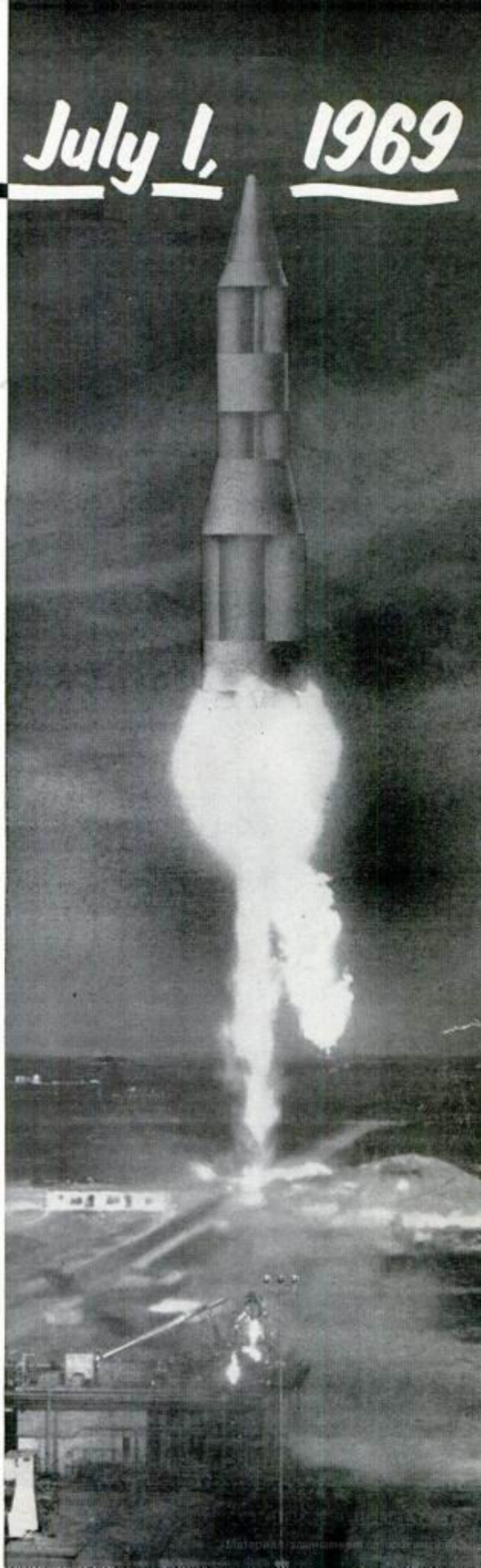
The next vehicle had been another “cone on a drum,” but the cone was flattened slightly on one side to form the cross section of an extremely thick “wing” with a small amount of aerodynamic control. Six months earlier, this capsule and the engines in the attached module, or drum, were sent around the moon and back to earth. The slight flattening of the cone—the only part of the space vehicle to return to earth—allowed pilot-navigator Henry Collins some slight guidance of the capsule as it reentered the atmosphere.

The capsule that faced Navy Lt. Comdr. Collins, his two companions, and Cooper, again was a cone that appeared very slightly flattened. Its base was 12 feet in diameter; the cone was 14 feet long. Below the cone was the familiar drum containing the two small hydrogen-lox engines that would propel the three men home from the moon. Below the propulsion module was again a trailer, but much longer this time. Here

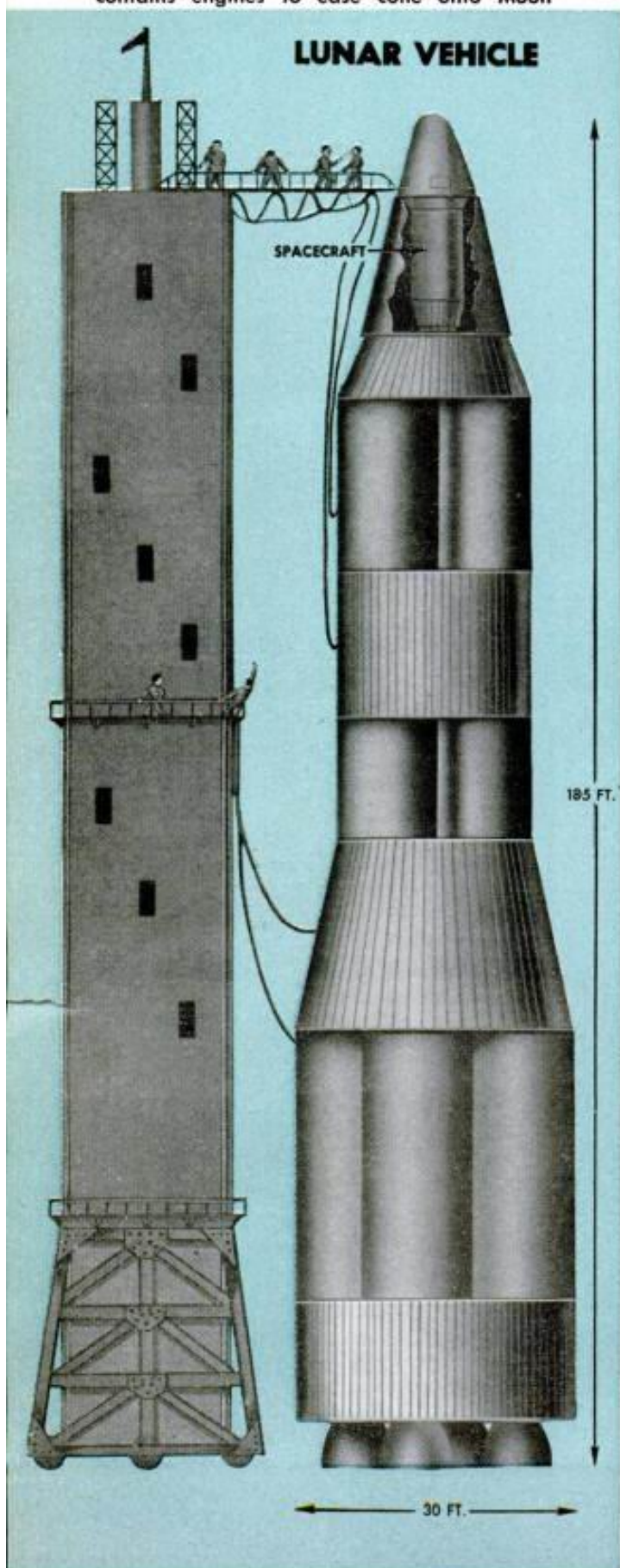
Rendezvous en Route?

three-stage rocket than the design shown here, exists at this writing only in the form of a contract which has been let for design feasibility studies, and actually is intended for orbital rendezvous and perhaps circumlunar shots, but not direct moon landings. Experts estimate that any Saturn C-5 shot cannot take place until 1966.

There is no doubt that in later years, once a rendezvous technique has been perfected, it will be a cheaper and less complex way to reach the moon than direct ascent. However, this article discusses our *first* moon trip, and all evidence indicates it will be made in the rocket shown here.



APOLLO SPACECRAFT, which will carry three men to moon and return, rests atop three-stage lunar vehicle—185 feet in air. Base of vehicle is 30 feet across. Men ride to moon in nose cone. Cylindrical "trailer" contains engines to ease cone onto Moon



were the hydrogen-lox engines that would ease the Apollo onto the moon.

Collins strode across the narrow catwalk and grasped two small, recessed handles on the entry hatch. An effortless pull and the lid lifted out two inches and then slid downward on tracks. Collins stepped through the hatch into the control cabin, tightly packed with engine control, navigation, communication and life-support equipment. Suspended above him was his "station" for launch and reentry and for control functions during flight.

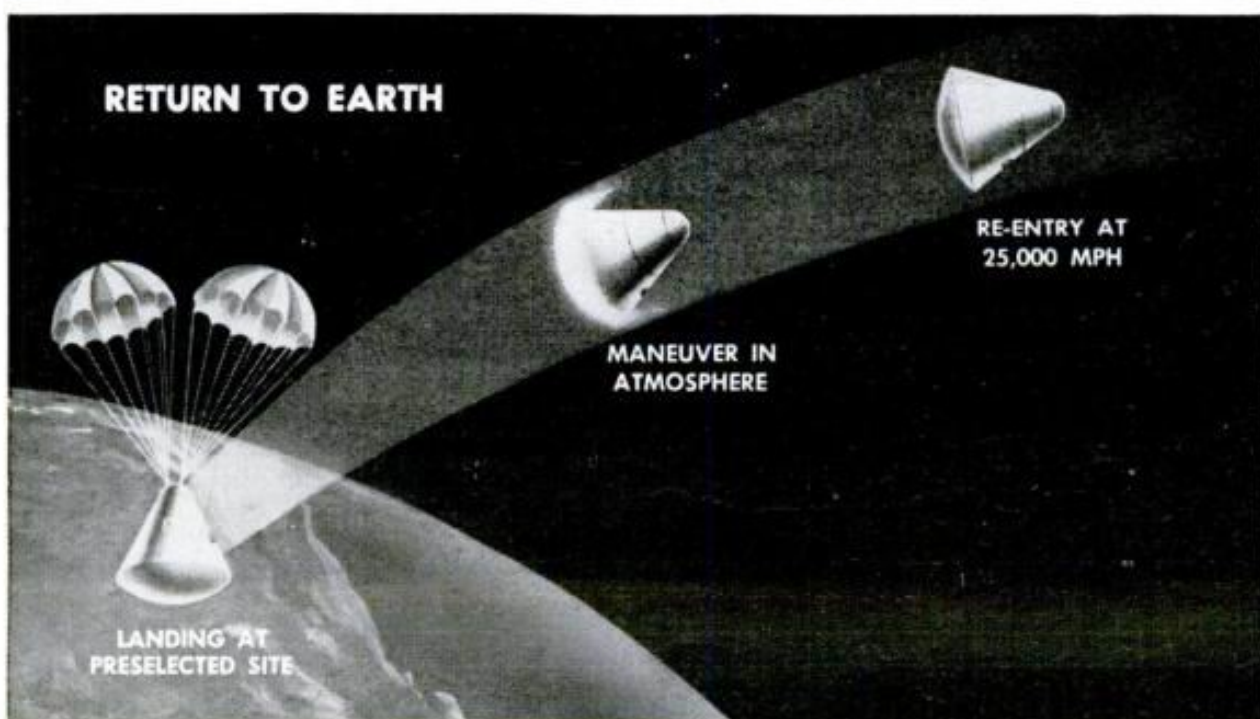
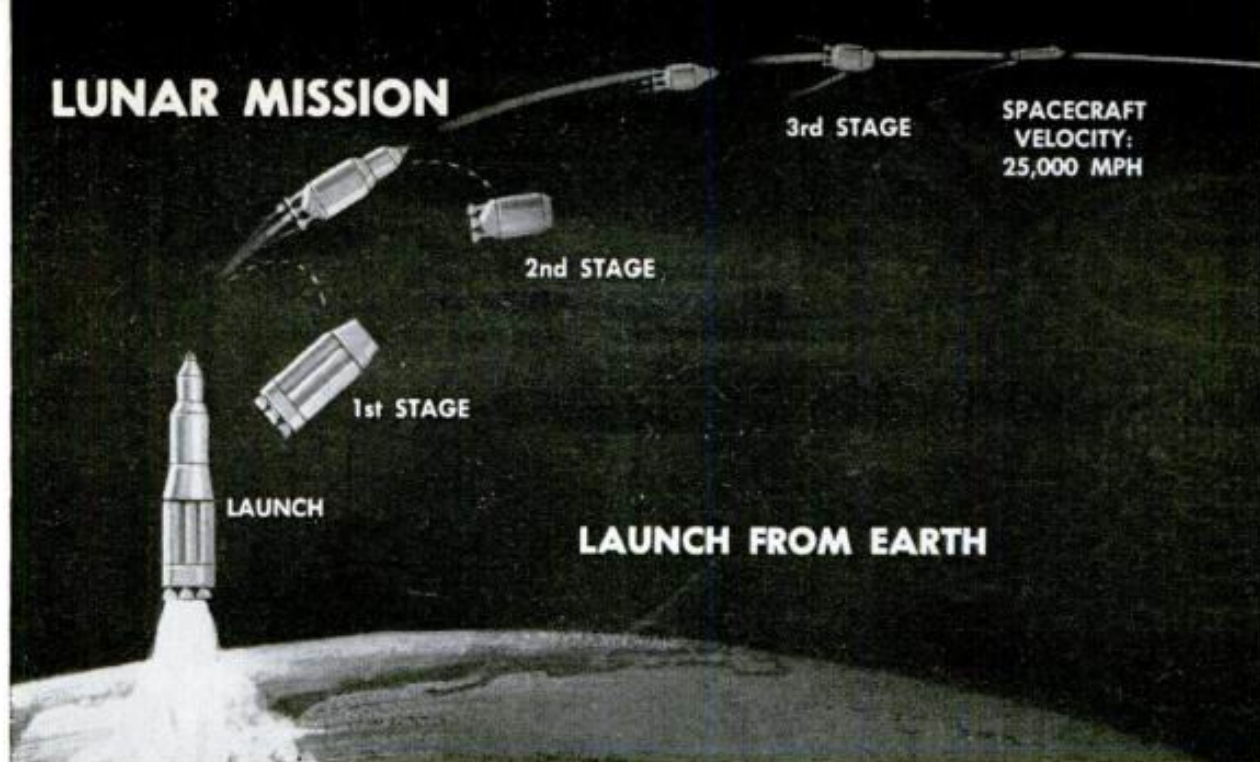
The station was a form-fitting bunk molded, in hard plastic, to Collins' body contours. It was on a three-way gimbal controlled by a motor and gyroscope to maintain a preset relative attitude as the capsule changed flight directions. Mounted on the gimbaled station were a full set of controls, which would guide the crew's destiny after the ground-controlled launching, and navigating equipment.

Below Collins' station were two others. Almost identical was the pilot-communicator's station assigned to Air Force Major Frank Dinswood. It featured a duplicated set of engine and emergency controls. However, only minimum emergency navigation equipment surrounded the pilot-communicator's station which featured, instead, the major equipment for communication between Apollo and Earth.

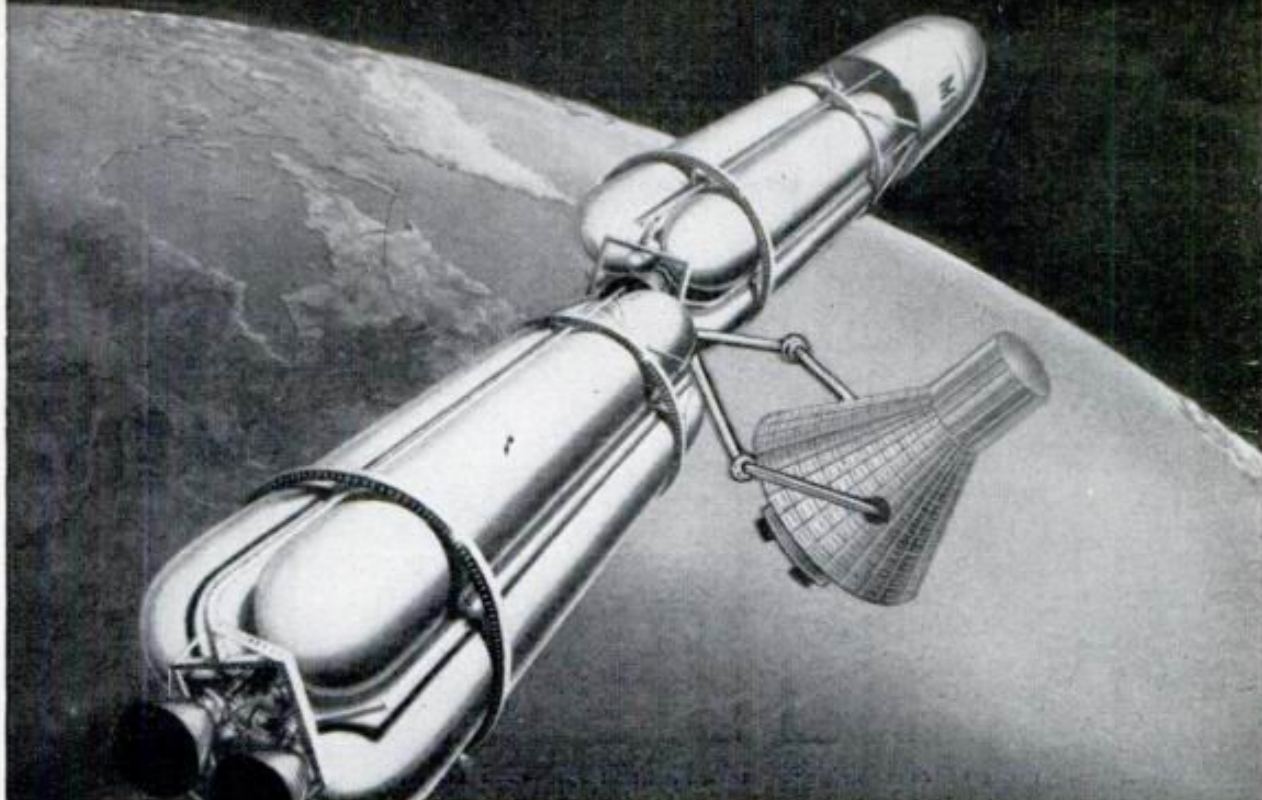
Beside Dinswood's station was another form-fitting acceleration couch, molded to the form of Air Force Captain William Hixson. As engineer-medic-scientist for the mission, Bill Hixson would be surrounded by controls for the capsule's oxygen and nitrogen breathing system, air-conditioning controls, instruments to record temperature, humidity, and every other critical factor of crew life and capsule. Hixson's station also featured the mission's tool box. Although he was the crew member most intensively trained in mid-flight repair and the use of the special space tools, Collins and Dinswood also had been checked out on the use of the tools and, of course, were on intimate terms with the rocket and capsule construction and plumbing so that they could also make emergency repairs.

It was Hixson, though, who had spent weeks learning the intricacies of space-tool use. In a weightless condition, there would be no gravity to provide one element of leverage and a major element of friction.

LUNAR MISSION includes these three phases. Launch from Earth gets spacecraft to escape velocity with three-stage booster. On lunar takeoff, "trailer" of spacecraft is left behind; only nose cone takes off. On return to Earth, cone maneuvers to land



ALTERNATE METHOD WITH ORBITAL RENDEZVOUS



ORBITAL RENDEZVOUS sends separate stages into orbit, mates them in space with help of two-man spacecraft

touched a switch with the little finger of his left hand and two padded steel bands dropped over his helmet and clamped it firmly to the couch. Then he activated another switch with his thumb and spoke into his helmet microphone. He told the blockhouse that he was strapped in and there was now room for Hixson to come into the cabin and go through the same procedure. The little finger operated the helmet clamps since that function would be performed only when the craft was at rest or relative rest and no great strength was needed. The strong thumb could activate the principal radio switch even during 15 or more G's of acceleration or deceleration. The even stronger index finger was saved for the manual emergency abort switch. It was separated from the thumb—no room for error here—by nature's own spacing on the hand. No switch was assigned to the third finger as this could lead to confusion.

After Hixson and Dinswood both were strapped in, Cooper gave them an encouraging high sign and departed. Then began the solid hour of checking equipment and checking instruments against their counterparts' readings in the blockhouse.

The principal control panels—those facing Collins and Dinswood—were changed only a little from the instrument consoles of the Mercury-Redstone 4 in which Air Force Capt. Virgil Grissom hopped from Florida to the Bahamas eight years earlier. However, there were more panels. There were complete controls over deceleration

and landing on the moon, entry and exit hatch, moon blast-off and, finally, the atmosphere re-entry and landing. Almost all controls operable by the crew were also automatic or semiautomatic in the character of the spacecraft.

The pilot-communicator could relay the navigator's position readings to Earth, or the communication equipment could be commanded to do it automatically at preset times. The engineer could willfully control the cabin temperature or humidity in response to what he might call an emergency or a deviation, or he could allow the automatic system to take its course and make probably the same compensations.

While the spacecraft and blockhouse crews were making checks and comparing notes, other crews were checking elsewhere around the globe. At the Goddard Space Flight Center, just outside of Washington, the computers were humming with "programmed dry runs" of the flight and crews were checking each action that would be made later in following the flight so that instant communication to Lunar Program headquarters in Houston could alert a controller to make a ground-command adjustment—if possible—in a wayward flight. At Jodrell Bank, England, the huge radiotelescope was pacing and repacing the first hour's flight. Half a world away, in southwest United States, the giant tracking station at Goldstone was checking frequencies, tracking and re-tracking over the anticipated flight.

(Continued to page 228)

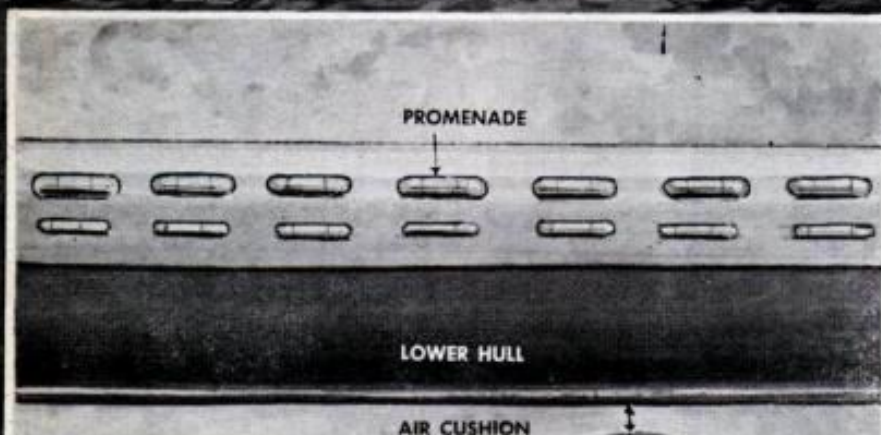
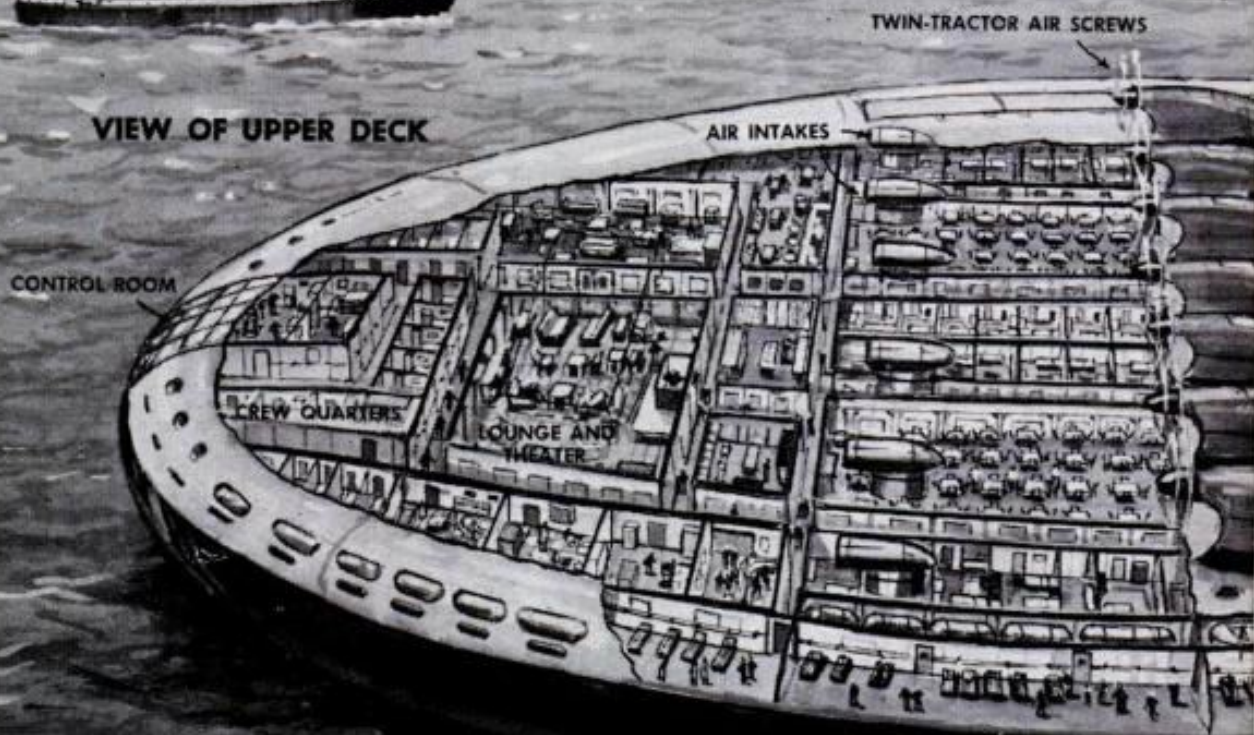
SIDE VIEW OF "MARINE FLYING SAUCER"



GREATEST CUSHION PRESSURE IS IN CENTER OF SHIP. IT IS RETAINED THERE BY FORE-AND-AFT BLASTS FROM FANS

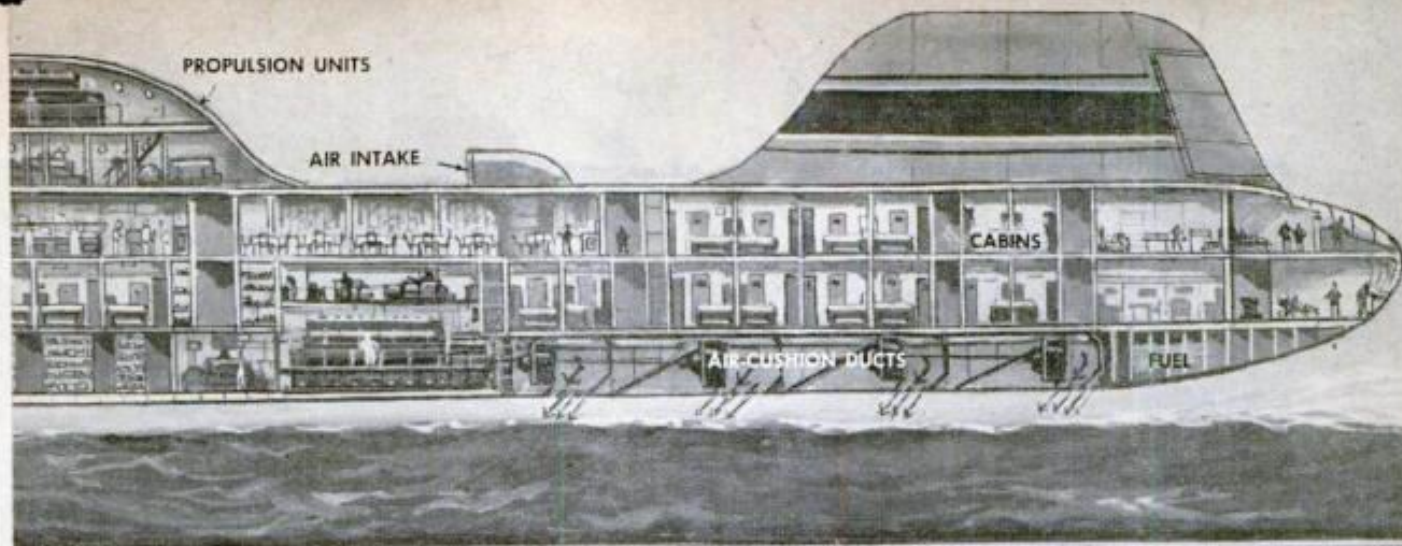


VIEW OF UPPER DECK

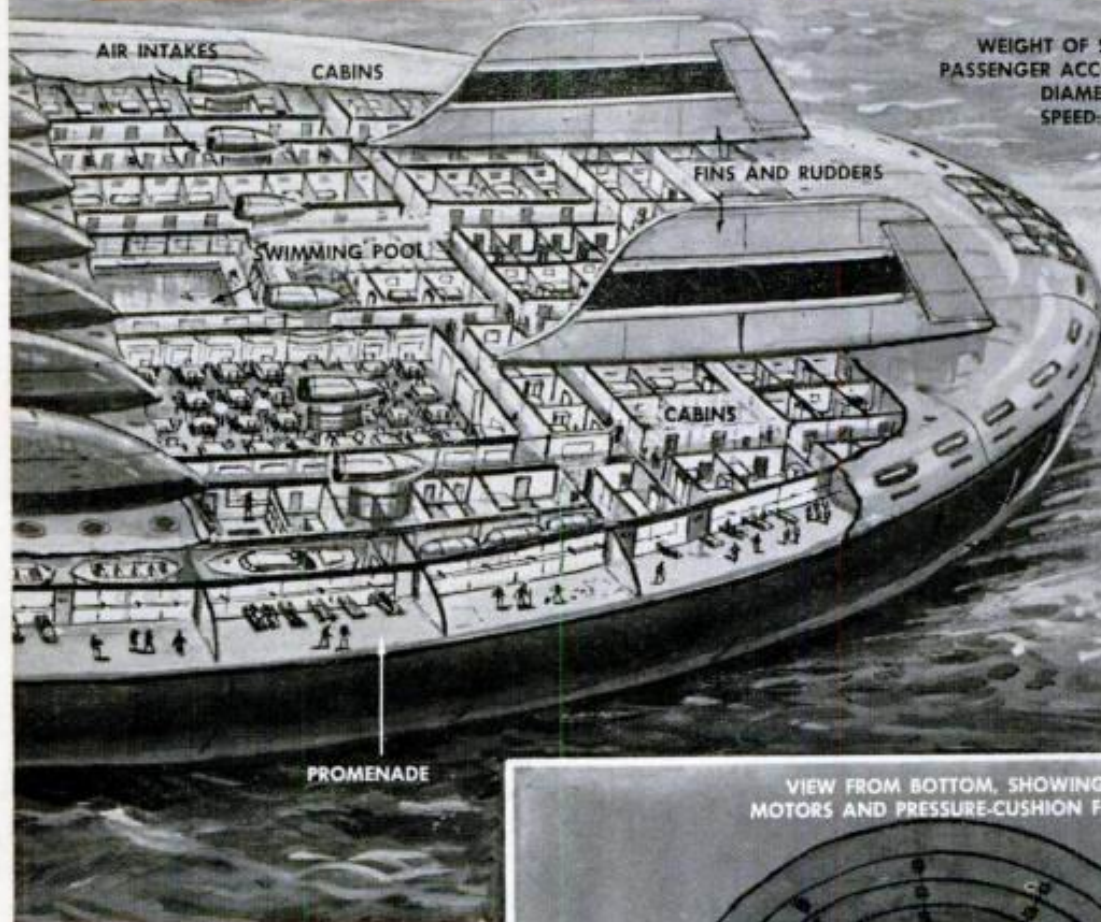


AVERAGE HEIGHT OF ATLANTIC WAVES: 8 FT. AVERAGE HEIGHT OF ATLANTIC WAVES IN GALE: 18 FT. SHIP WOULD BE HELD APPROXIMATELY 8 FEET ABOVE ALL CRESTS. BECAUSE SHIP HAS NO DIRECT CONTACT WITH SEA, IT REMAINS STABLE IN ALL WIND AND SEA CONDITIONS

OCEAN VOYAGERS may some day travel on a vessel that rides a few feet above water and crosses the sea at 100 knots. Such a vessel would look like the marine "flying saucer" shown on these pages, which was designed by Swiss engineer Carl Weiland and drawn for *Popular*



SEAGOING SAUCERS AHEAD?



WEIGHT OF SHIP: 40,000 TONS
PASSENGER ACCOMMODATIONS: 1000
DIAMETER: 330 FT.
SPEED: 100 KNOTS

Mechanics by the British artist, G. H. Davis. Skimming the surface as a hydroplane does, the vessel would ride on a cushion of high-pressure air created by huge fans fore and aft. The vessel's circular design would reduce to a minimum the escape of air from the cushion. ★ ★ ★

VIEW FROM BOTTOM, SHOWING MOTORS AND PRESSURE-CUSHION FANS



WRITTEN SO YOU CAN UNDERSTAND IT
VOL. 111 NO. 3

HIGH-VOLTAGE RAINMAKERS

By
Richard F. Dempewolf

DO RAINDROPS and other precipitation in a thunderstorm generate the tremendous electrical charges that enable it to produce sparks several miles long? Or do vast electrical fields generated by other forces in a growing thunderhead create the raindrops? If electricity comes first, as scientists Dr. Bernard Vonnegut and Charles B. Moore suspect, small generating plants may be able to "broadcast" an electrical charge into the free air, influence electrification of clouds and possibly stimulate rainfall in many places where it's needed.

For several years, Vonnegut and Moore, two prominent young scientists working out of Arthur D. Little Laboratories in Cambridge, Mass., have been chasing big black cumulus clouds to probe their secrets. From the 10,300-foot summit of Mount Withington in New Mexico—a thunderhead "factory" that

29,000 FEET

ICE CRYSTALS CAP CLOUD TOP
AT ABOUT 20,000 FEET

MASSIVE DOWN DRAFTS
PULL DOWN EDGES
OF CLOUD TOP

TETHERED BALLOON

PROBES
MEASURE
CLOUD'S
ELECTRICAL
FIELD

RADIOSONDE REPORTS
ELECTRICAL FIELDS
TO GROUND

P-38 FLIES AROUND,
ABOVE AND BENEATH
CLOUD TO PICK UP
ELECTRICAL FIELDS
OUTSIDE GROWING STORM

MANNED FREE
BALLOON NOT
DRAWN INTO
CLOUD

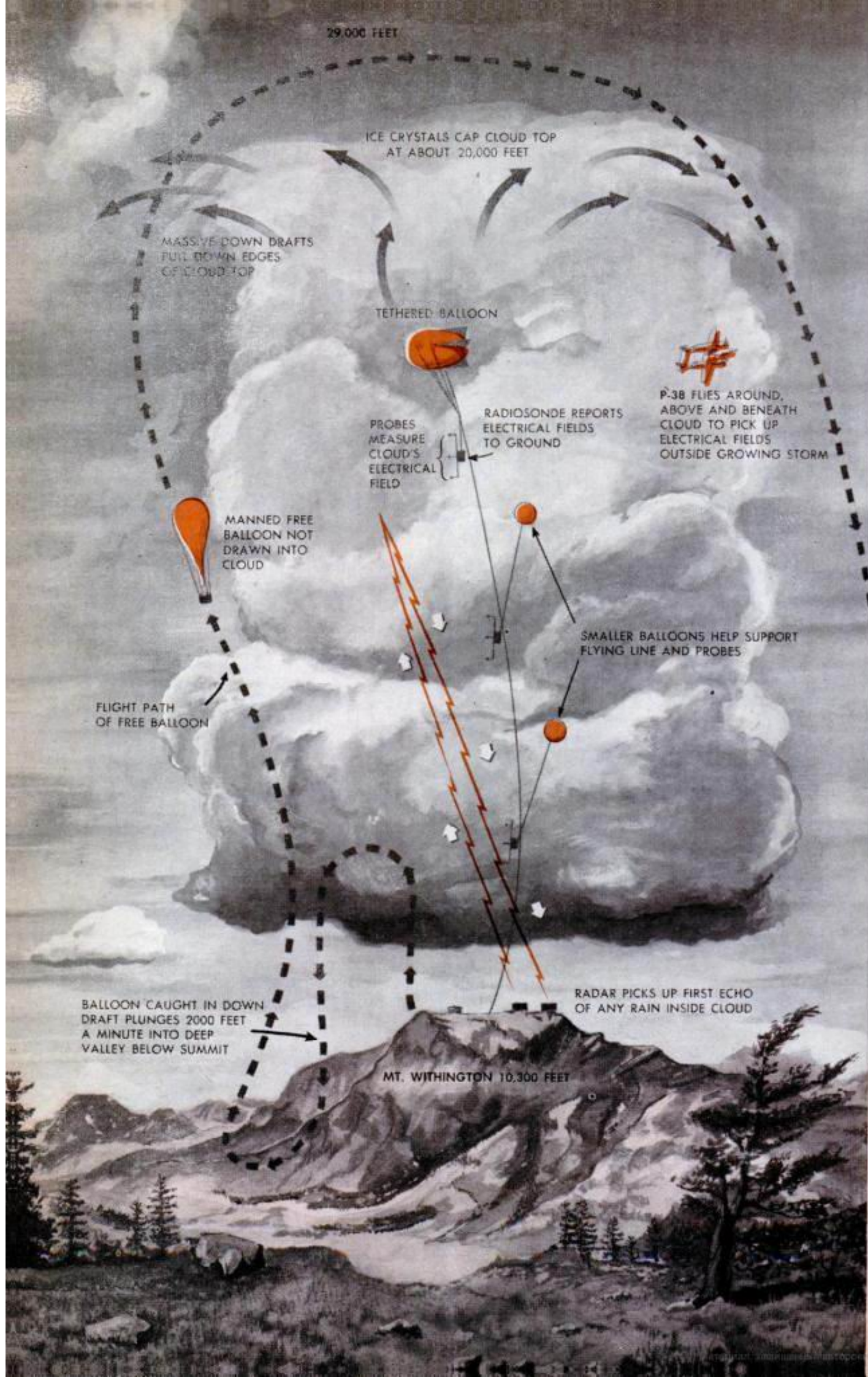
FLIGHT PATH
OF FREE BALLOON

SMALLER BALLOONS HELP SUPPORT
FLYING LINE AND PROBES

BALLOON CAUGHT IN DOWN
DRAFT PLUNGES 2000 FEET
A MINUTE INTO DEEP
VALLEY BELOW SUMMIT

RADAR PICKS UP FIRST ECHO
OF ANY RAIN INSIDE CLOUD

MT. WITHINGTON 10,300 FEET

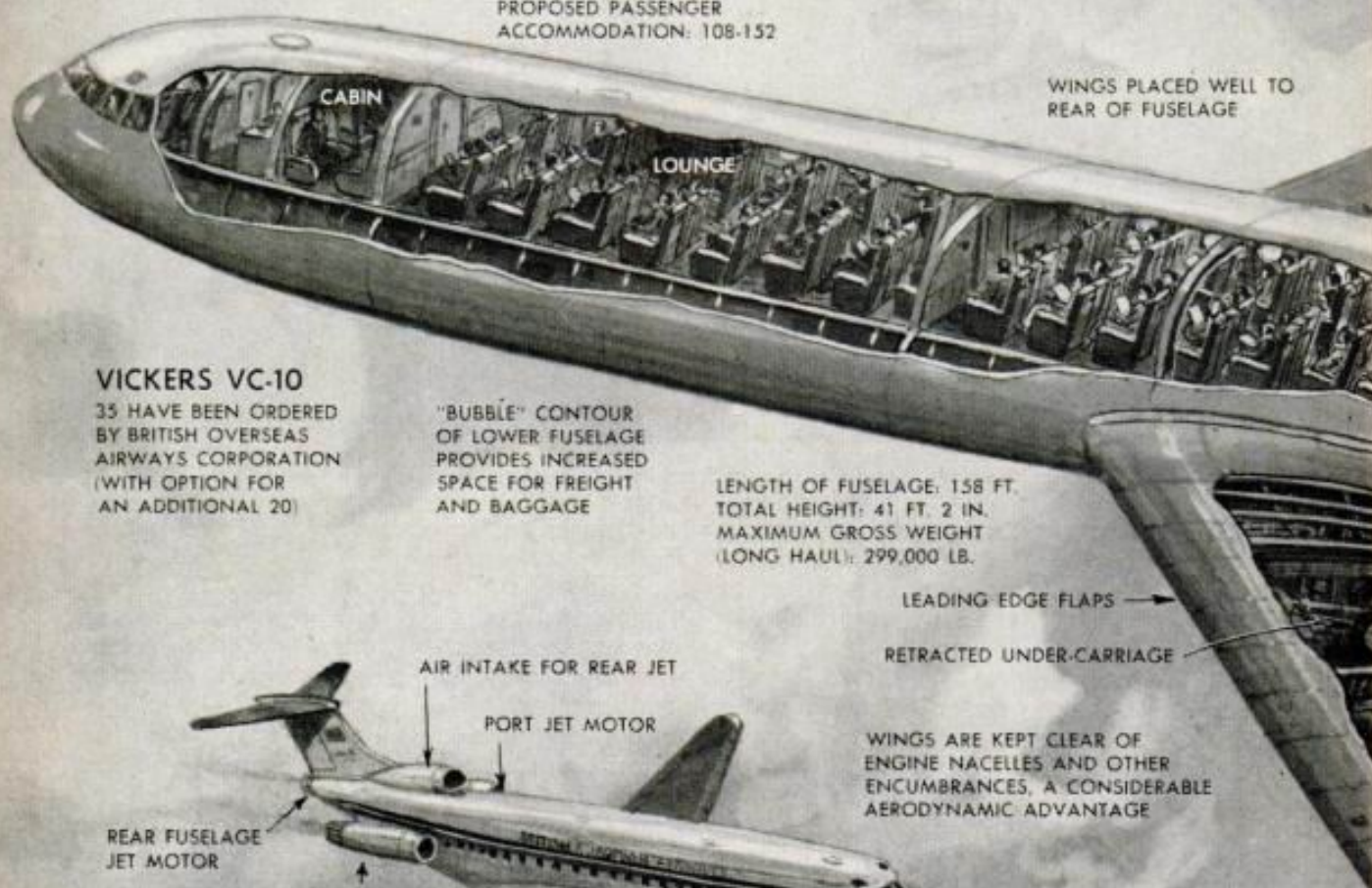


CROSS SECTION OF VC-10



BRITAIN BUILDS A REAR-ENGINE

PROPOSED PASSENGER
ACCOMMODATION: 108-152



VICKERS VC-10

35 HAVE BEEN ORDERED
BY BRITISH OVERSEAS
AIRWAYS CORPORATION
(WITH OPTION FOR
AN ADDITIONAL 20)

"BUBBLE" CONTOUR
OF LOWER FUSELAGE
PROVIDES INCREASED
SPACE FOR FREIGHT
AND BAGGAGE

LENGTH OF FUSELAGE: 158 FT.
TOTAL HEIGHT: 41 FT. 2 IN.
MAXIMUM GROSS WEIGHT
(LONG HAUL): 299,000 LB.

WINGS PLACED WELL TO
REAR OF FUSELAGE

LEADING EDGE FLAPS

RETRACTED UNDER-CARRIAGE



WINGS ARE KEPT CLEAR OF
ENGINE NACELLES AND OTHER
ENCUMBRANCES, A CONSIDERABLE
AERODYNAMIC ADVANTAGE

DE HAVILLAND DH 121

ORDERED BY BRITISH EUROPEAN AIRWAYS
FOR SHORT-HAUL SERVICES. MAXIMUM
PASSENGER ACCOMMODATION 100.
SPEED IN EXCESS OF 600 M.P.H.

THE VC-10 IS TO BE USED MAINLY ON AFRICAN AND EASTERN FLIGHTS OF THE B.O.A.C. THE ABSENCE OF WING ENGINES ALLOWS MAXIMUM SPACE FOR LANDING AND TAKE-OFF SURFACES, ENABLING THESE FAST AIRCRAFT TO USE THE HIGH-ALTITUDE AIRFIELDS SITUATED IN TROPICAL CLIMATES.





FRENCH AIRLINER "CARAVELLE,"
WITH REAR-MOUNTED JET MOTORS
(NOW IN PRODUCTION)

WINGS SWEPT BACK
APPROXIMATELY 40 DEGREES

JET LINER

SPAN 140 FT.

HIGH VARIABLE-
INCIDENCE TAIL-PLANE

STOWED LIFE RAFT

FUEL
TANK

SPOILERS

PORT SIDE TWIN ROLLS-ROYCE
CONWAY JET MOTORS, EACH
GIVING APPROXIMATELY 20,000 LB.
STATIC THRUST AT TAKE-OFF.
NOISE SUPPRESSORS FITTED ON ALL
ENGINES. THRUST REVERSERS ALSO USED

TWO JETS MOUNTED
ON STUB WINGS TO
PORT AND STARBOARD
(AFTERBURNERS WILL
BE FITTED FOR TRANS-
ATLANTIC RUN).
PLACING OF ENGINES
NEAR TAIL AIDS
PASSENGER COMFORT
BY DECREASING NOISE

G. HAVIS
1958

RUNWAY: 10,000 FT.

NAIROBI
TROPICAL
CLIMATE

HEIGHT
ABOVE
SEA LEVEL:
5327 FT.

THE NEW EMBAKASI AIRFIELD,
NAIROBI (KENYA, EAST AFRICA),
IS DESIGNED FOR USE BY FAST,
MODERN AIRLINERS AND AN ANNUAL
TRAFFIC FLOW OF 30,000 PASSENGERS



10,000-FT. RUNWAY
(AN ADDITIONAL RUNWAY
MAY BE LAID DOWN LATER
IF TRAFFIC DEMANDS IT)

LIGHTS

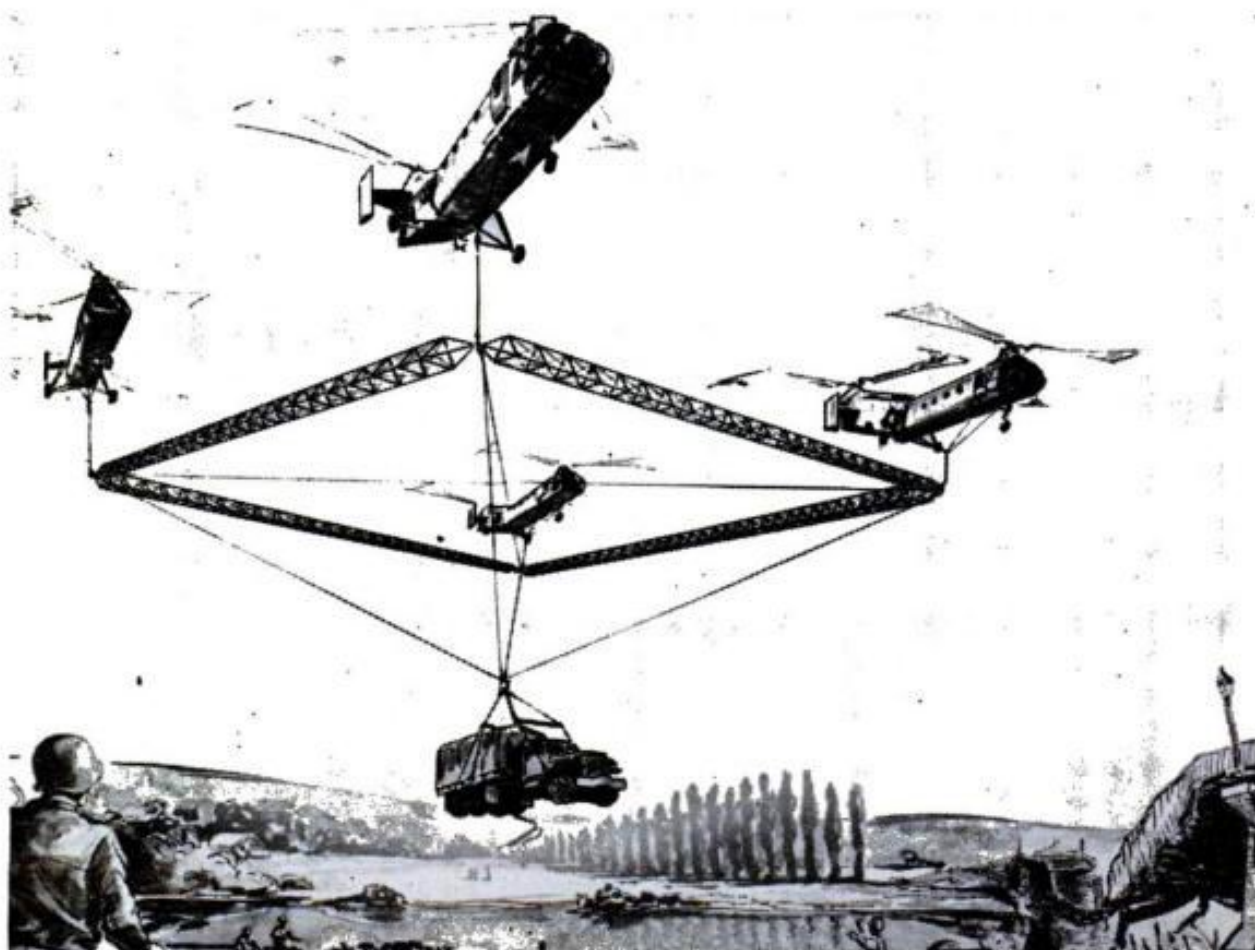




Workhorses of the Air

HELICOPTERS can be harnessed in teams of aerial workhorses, providing tremendous lifting power for short-haul delivery of heavy military vehicles and materiel to advanced combat areas. The copters can be harnessed in teams of two, three, four, five or six. Their heavy cargo, such as a 13,000-

pound truck, is attached by cables to aluminum-alloy spreader-frames. Ends of the frames are fastened together and the copters are attached to the frames by suspension cables. Each frame is 113 feet long and weighs 400 pounds. Vertol Aircraft developed the method for the Army.



POPULAR MECHANICS

FEBRUARY
1958

WRITTEN SO YOU CAN UNDERSTAND IT
VOL. 109 NO. 2



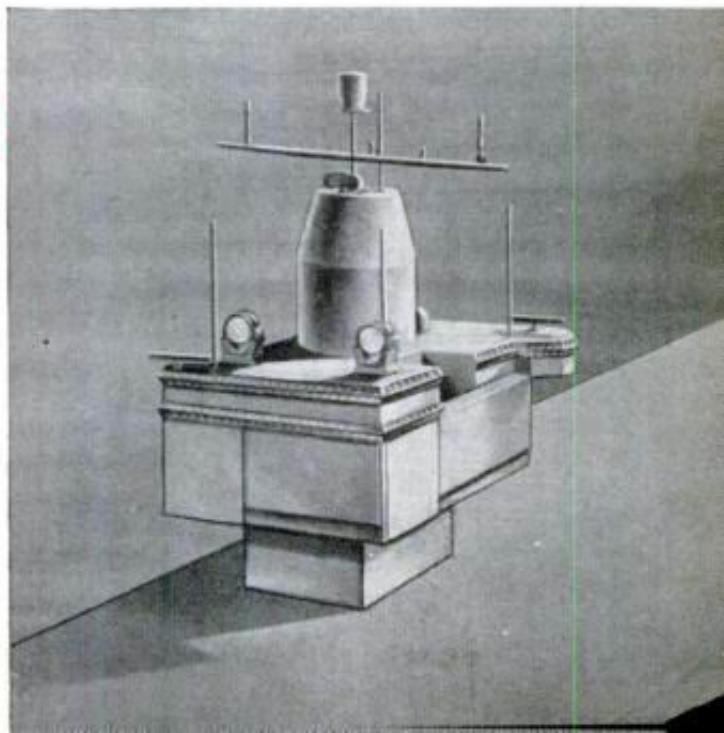
Atomic Revolution In the Shipyards

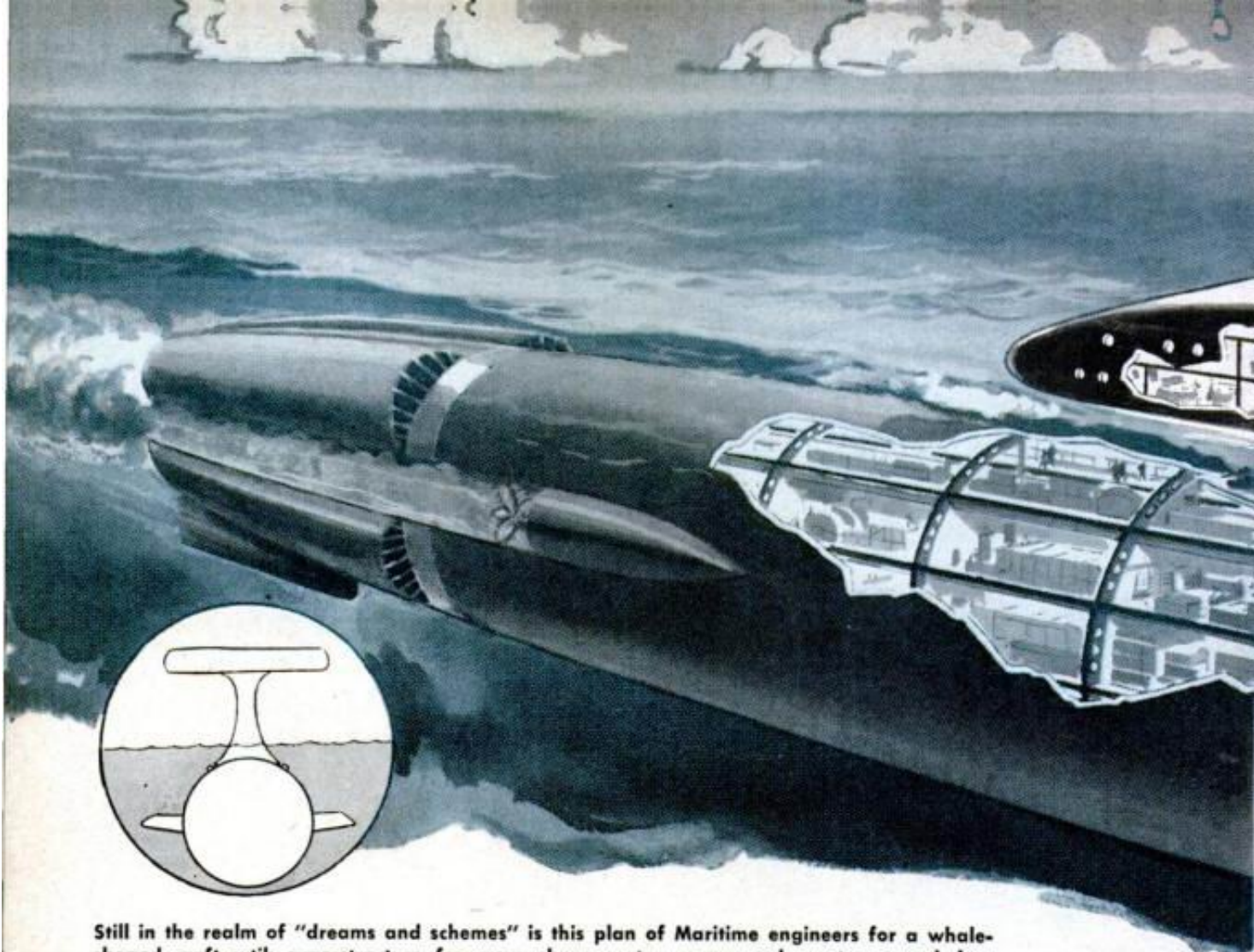
By Michael Day

*Richard
Dempsey*

IT WAS 75 YEARS after the invention of steam power before the first steamship appeared," Rear Adm. Albert G. Mumma, chief of the Navy's Bureau of Ships, pointed out recently. "But in just 12 years after atomic power was unleashed, our first nuclear subs were operating. In another five years we will be well on our way to a complete nuclear fleet. This spells a real revolution in ship design."

Only protrusion on deck of the big nuclear-powered carrier above will be "electronic" island, at right





Still in the realm of "dreams and schemes" is this plan of Maritime engineers for a whale-shaped craft with superstructure for crew above water, cargo and reactor area below

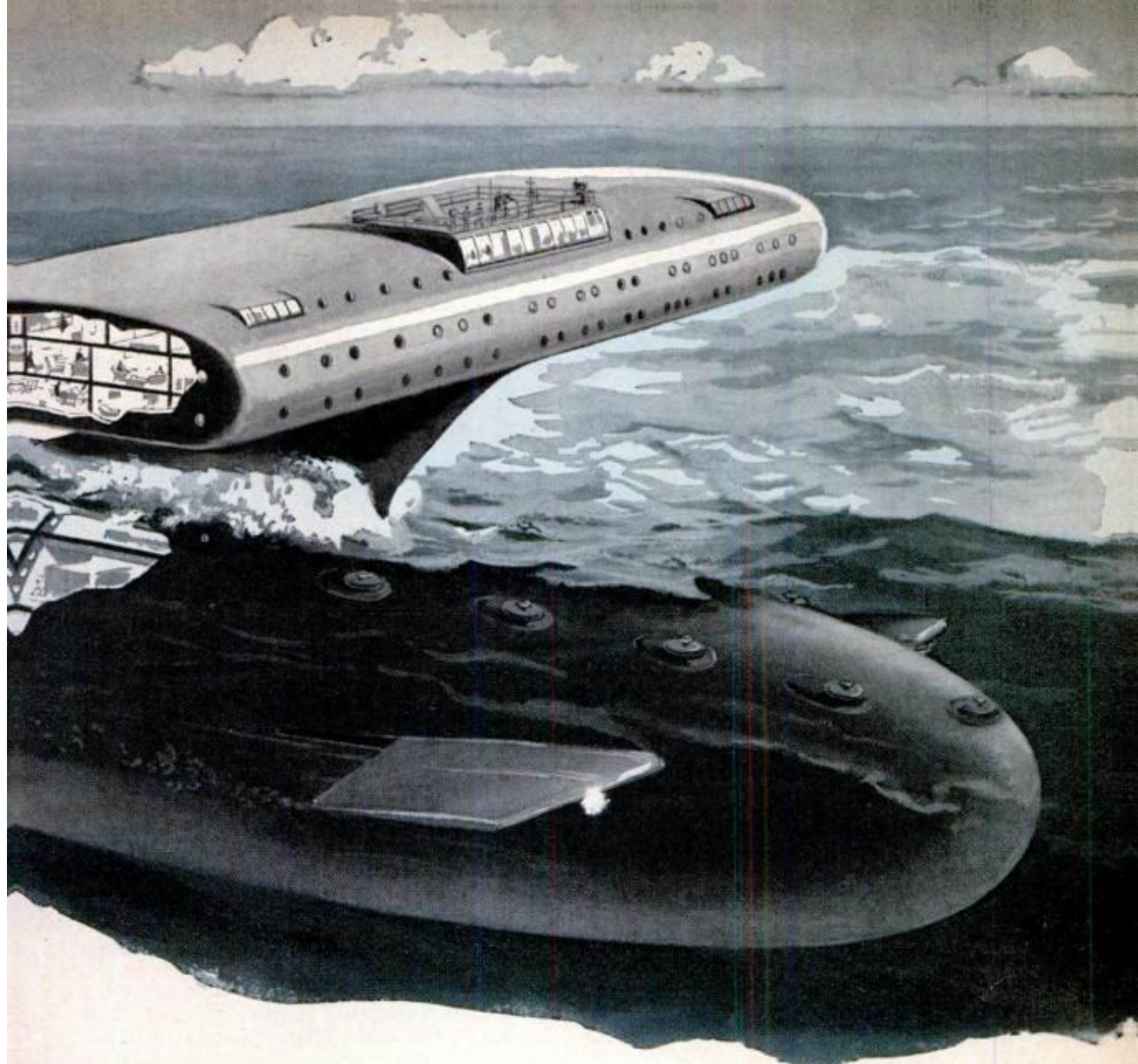
Even a nautically minded Buck Rogers might boggle before the new breed of ship that is destined to thunder down the world's ways in the next half decade as a result of this "revolution."

In the United States alone, the *Nautilus* and *Seawolf*, our operating nuclear-powered submarine prototypes, already have spawned a whole new seagoing family of atomic ships that will start hatching this year. By 1961, nineteen atomic subs will be launched or a-building. Whale-shaped nuclear "attack subs" will "fly" at phenomenal speeds under the sea the way a plane flies through the air, pilot and co-pilot strapped to bucket seats while crew members grab for leather loops like subway straphangers as the weird craft executes high-speed turns at a 30-degree bank. We're building small hunter-killer A-subs; a giant radar picket sub powered by two reactors and displacing a thumping 5450 tons (biggest World War I fleet-type subs displaced only 1900 tons); guided-missile A-subs, each housing a Regulus stinger in a below-decks missile hangar that is itself the size of a current fleet submarine; fast, fleet-type A-subs with minimum shielding, in which crews will crawl through lead-lined tunnels around the reactor section. Besides

undersea craft, a mammoth keel will soon be laid for the biggest ship in the world—our 85,000-ton atomic super carrier, driven by eight separate nuclear power plants. And within three years, the fantastic two-reactor guided-missile cruiser *Long Beach*, her stackless deck bristling with weird launchers and rakish "birds," will take to the water with an estimated speed potential of 40 miles per hour. In addition to Navy plans, a joint Atomic Energy Commission-Maritime Administration program will put our first atomic cargo-passenger liner afloat sometime early in 1960.

Though sponsoring the most spectacular atomic splash in the ocean, the United States isn't the only entry in the A-ship race by any means. The British Royal Navy's first atomic submarine is already on the drawing boards and her engineers are studying the economics of a 65,000-ton nuclear-powered oil tanker. Sweden is also building an A-tanker.

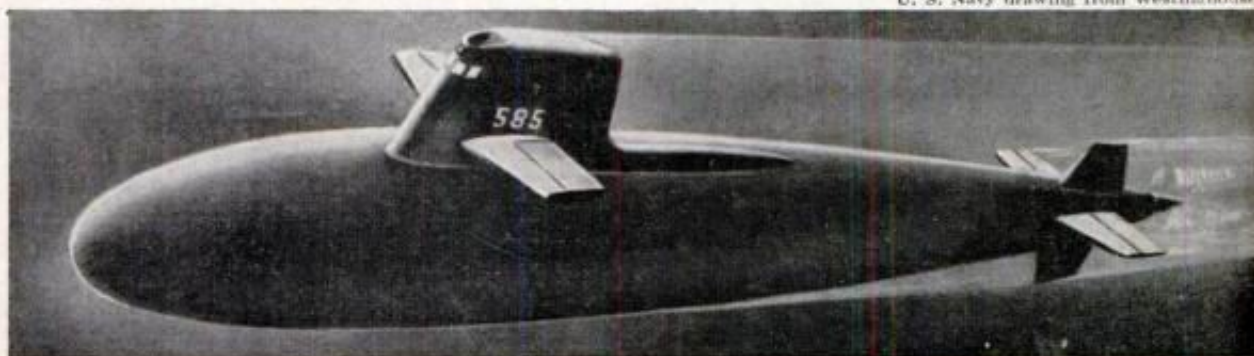
In a Leningrad shipyard, Russia early in December launched a 22-knot atomic ice breaker whose 16,000-ton displacement would make her the world's mightiest. More recent announcements over Radio Moscow hint at a winged A-ship that will ride about a foot above the water.

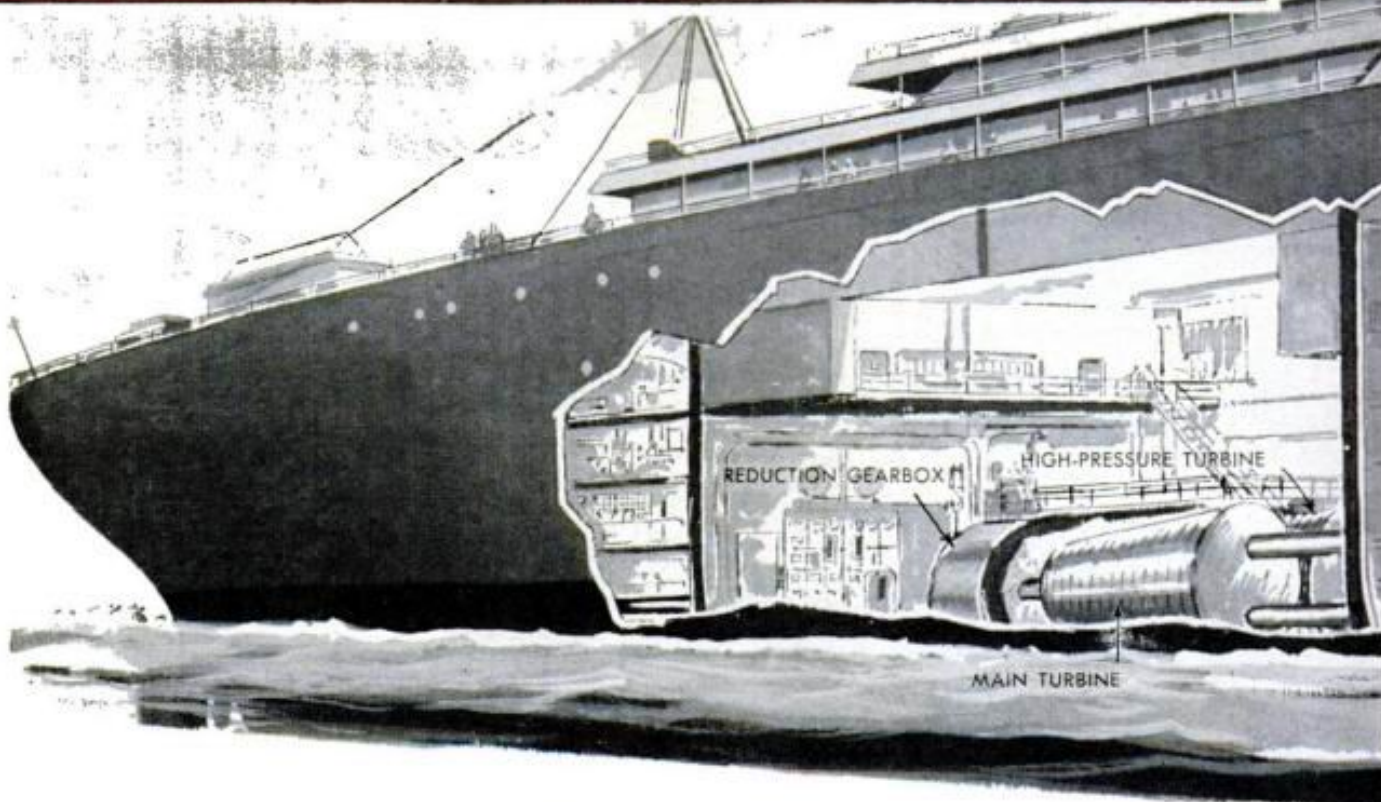
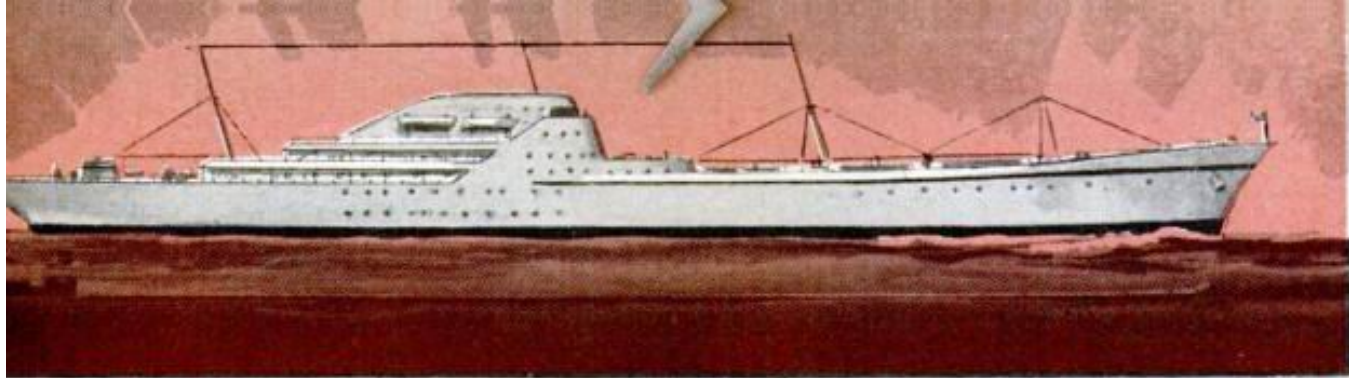


Japan has already blueprinted plans for one of the most unusual A-ships of all—a 30,000-ton submarine atomic tanker, 540 feet long, that can run its cargo smoothly beneath the surface in any weather. Snorkel-type intake and exhaust equipment will provide air for the crew, enabling the unique A-tanker to ride submerged for a month at a crack.

Just what these ships will be able to do, what it will be like to ride them, how their seagoing atomic piles will change their appearance and performance, still is partly veiled in secrecy. But curious details keep emerging. Scouting through the Navy's Bureau of Ships and the busy design section of the Maritime Administration you begin to feel the impact of atomic

Artist's conception of the USS Skipjack, an atomic-powered submarine with diving planes on the tower
U. S. Navy drawing from Westinghouse



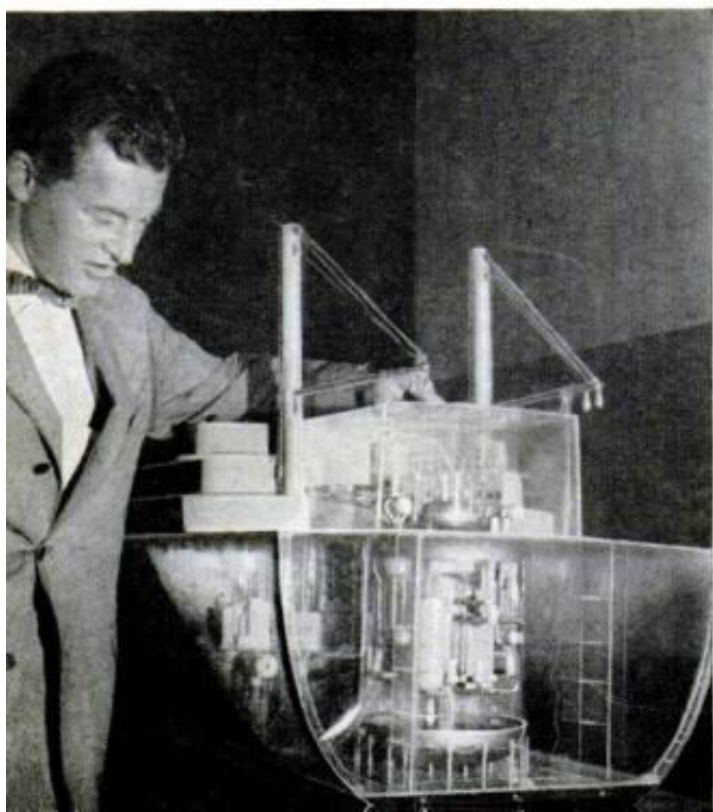


Drawings of atomic merchant ship show (top) how it will look at sea and cutaway of atom-power plant

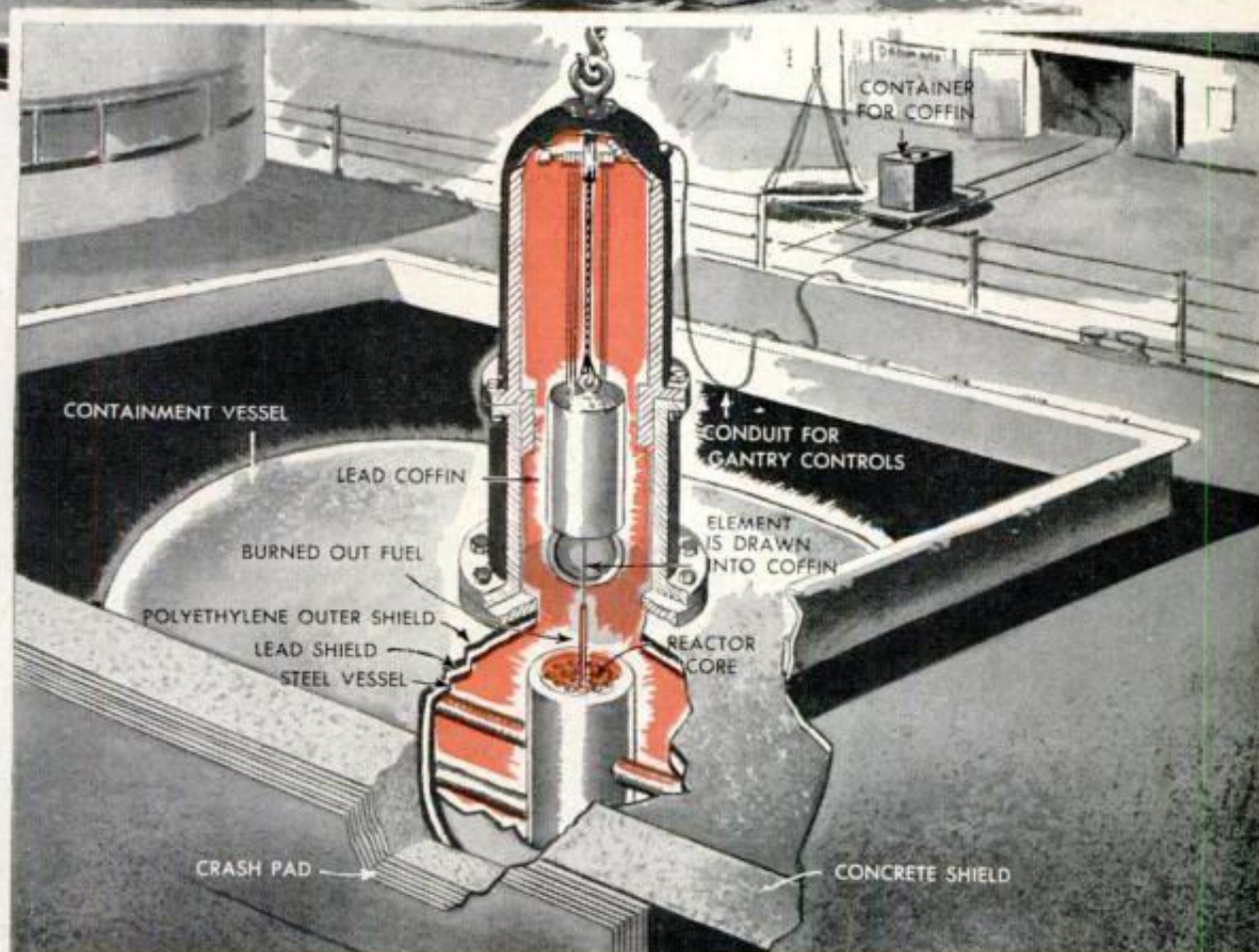
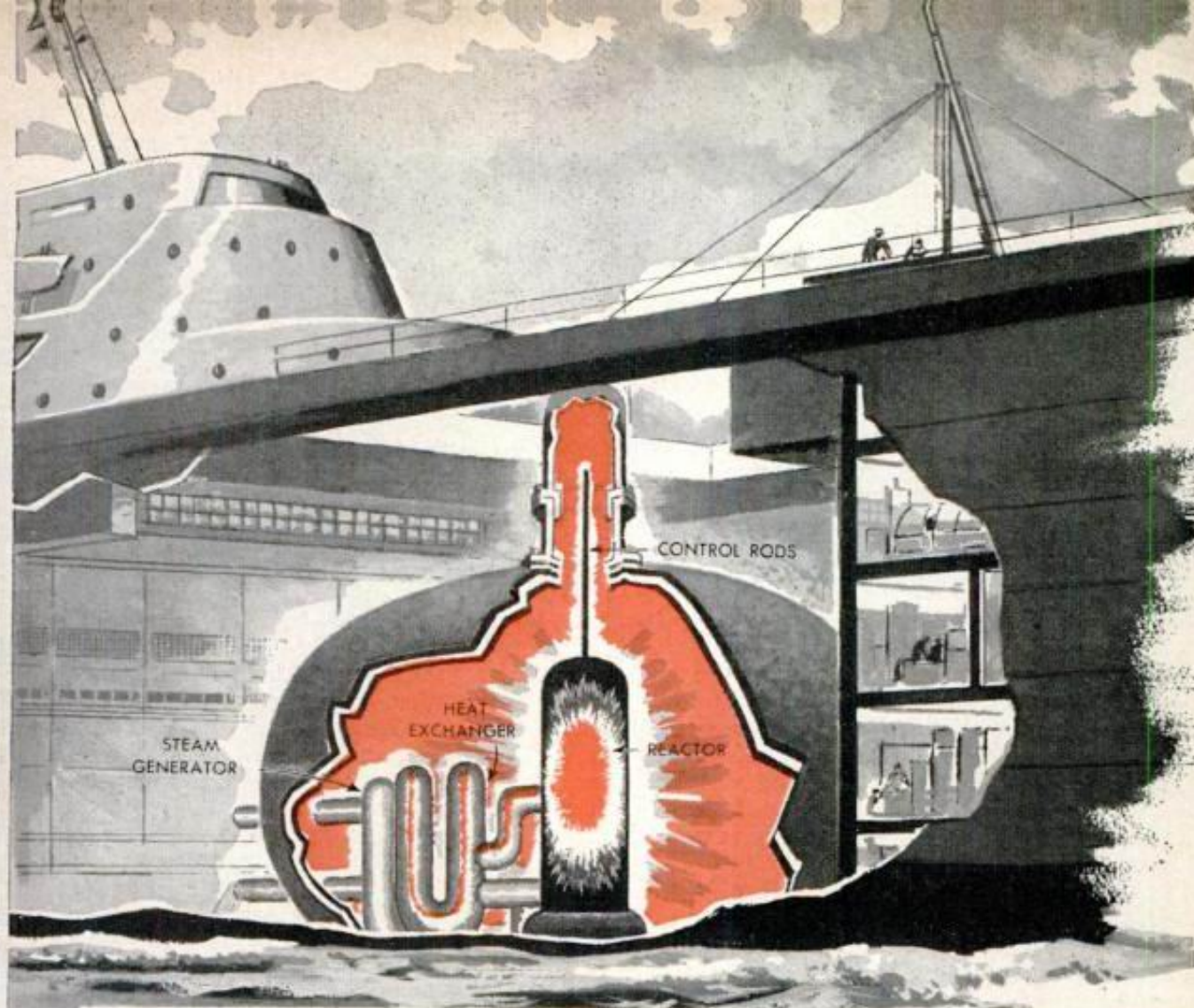
revolution as stories of some of these fantastic ships fall upon your ears.

Most exciting to the Navy of all its atom

Richard P. Godwin, project director of the atomic merchant ship, inspects model of reactor for tanker



ships is the nuclear super carrier. This \$314,000,000 seagoing airport is due to start building this year. Without doubt it is the most complex weapon ever contrived by man. Stretching more than a long city block (1100 feet) from stem to stern with an over-all width of 251 feet, and 25 stories high from keel to the top of the odd lid on its island, this Gargantua surpasses the mighty *Forrestal*-class carriers that it will eventually outmode. She has 4000 square feet more flight deck and 2000 square feet more hangar deck than her *Forrestal*-type forerunners. A crew of more than 4000 will be needed to man her, and her eight separate reactors, hitched in tandem pairs via geared turbines to each of four massive shafts, would be capable of producing electricity for a city of a million people—with enough juice left over to push the ship as well. Each reactor, labeled LSR (for "Large Ship Reactor"), will be an expanded version of the pressurized water reactor that has so successfully powered the *Nautilus*. How fast these fabulous power sources will push the floating airfield through the water no one will tell—if





Sluice gates in proposed dam allow waters of rising tide to rush into river basin. Dam is 2100 feet long

France Is Harnessing the Tides

By R. N. Hadden

Drawings by G. H. Davis

WITHIN THE NEXT DECADE, the world's first tidal-power station will start to supply electrical power to the people of France, thus realizing one of man's oldest dreams—harnessing the sea.

Plans for this huge power station are well advanced. It will be built on the estuary of the river Rance, where twice every day the tide rises and falls between 7 and 41 feet. When this power station is completed it will produce about 800,000,000 kilowatt hours a year, according to the French engineers who have been working on the project.

How will this power station derive its energy from the tides? Simply by capturing the water behind the dam at high tide and then releasing it to turn the turbines. However, this is not quite as simple as it sounds as is evidenced by the diagrams on page 88.

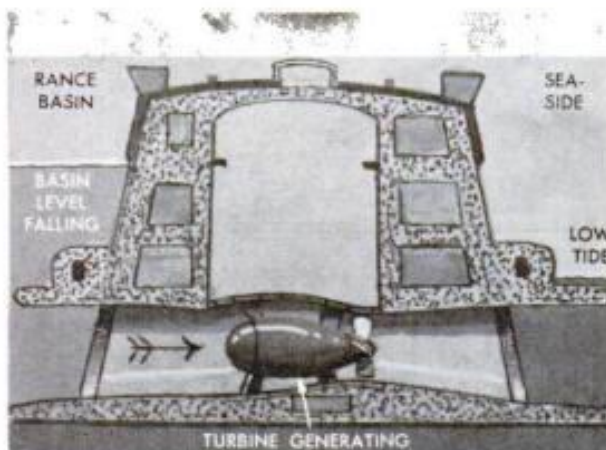
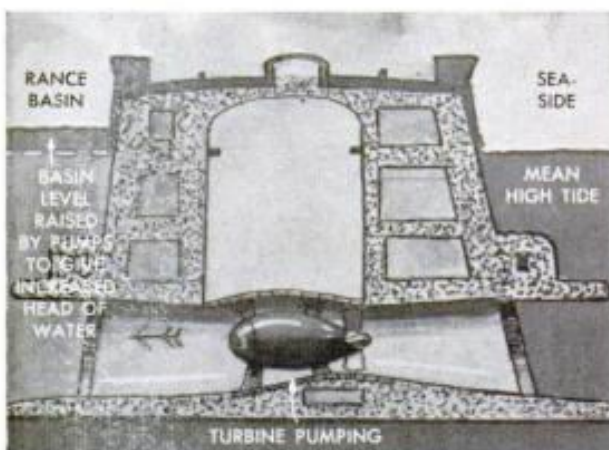
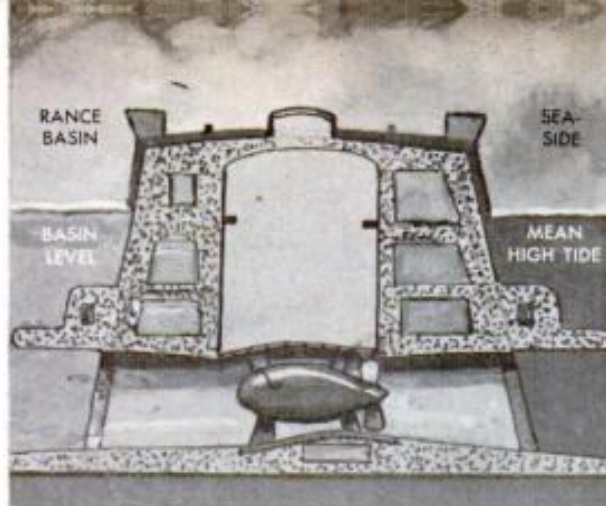
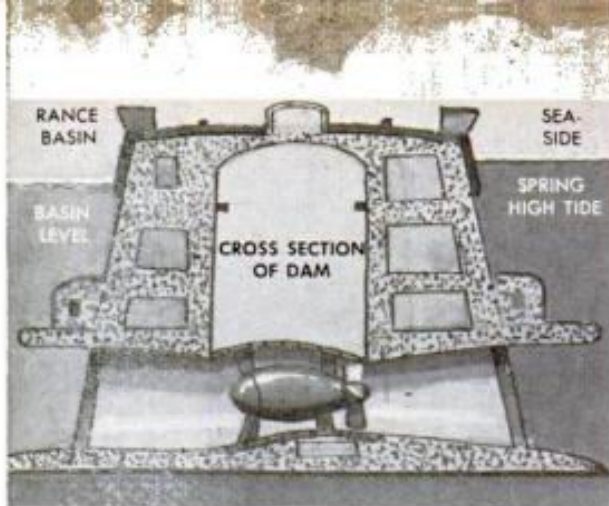
The dam will be constructed across the estuary at a point where the distance from shore to shore is 700 yards. Turbines and generators will be located within the dam which will be 150 feet wide at the base. Giant sluice gates will be about 27,000 square feet in area.

JUNE 1957

BUILT BY:
ELECTRICITÉ DE FRANCE
68 RUE DU FAUBURG—ST. HOUCRE
PARIS SE, FRANCE

85

Материал, защищенный авторским правом



Drawings show how the dam operates with respect to river and seaside water levels. Turbine also pumps

This is how the tidal "harness" will operate: Shortly after low water the sluice gates will be opened. When the tide rises, water will rush through the gates and fill the channel above the dam. When the channel has been filled the sluice gates will be shut. The turbines will then be started up in reverse to act as pumps, the generators serving as motors. The power taken for this operation will be obtained from France's existing electrical network. More water will be pumped from the sea into the channel above the dam.

When the difference in level between the water behind the dam and the falling tide has increased to four feet, the pumping will be stopped. Three hours after high tide the turbines will again be started up, but this time to run as turbines. Electricity will then be fed into the country's power network. The turbines will continue to run until just after low tide when the levels below and above the dam will again be equal. The cycle will then be repeated, electricity being produced for 10 hours in every day.

The reason for the pumping operation may not be quite obvious at first. It has, however, been found from model tests, that the small amount of power absorbed in pumping, when the difference in water level is small, produces a much greater quantity of power when the same water flows through the turbines under a higher head caused by the falling tide. In other

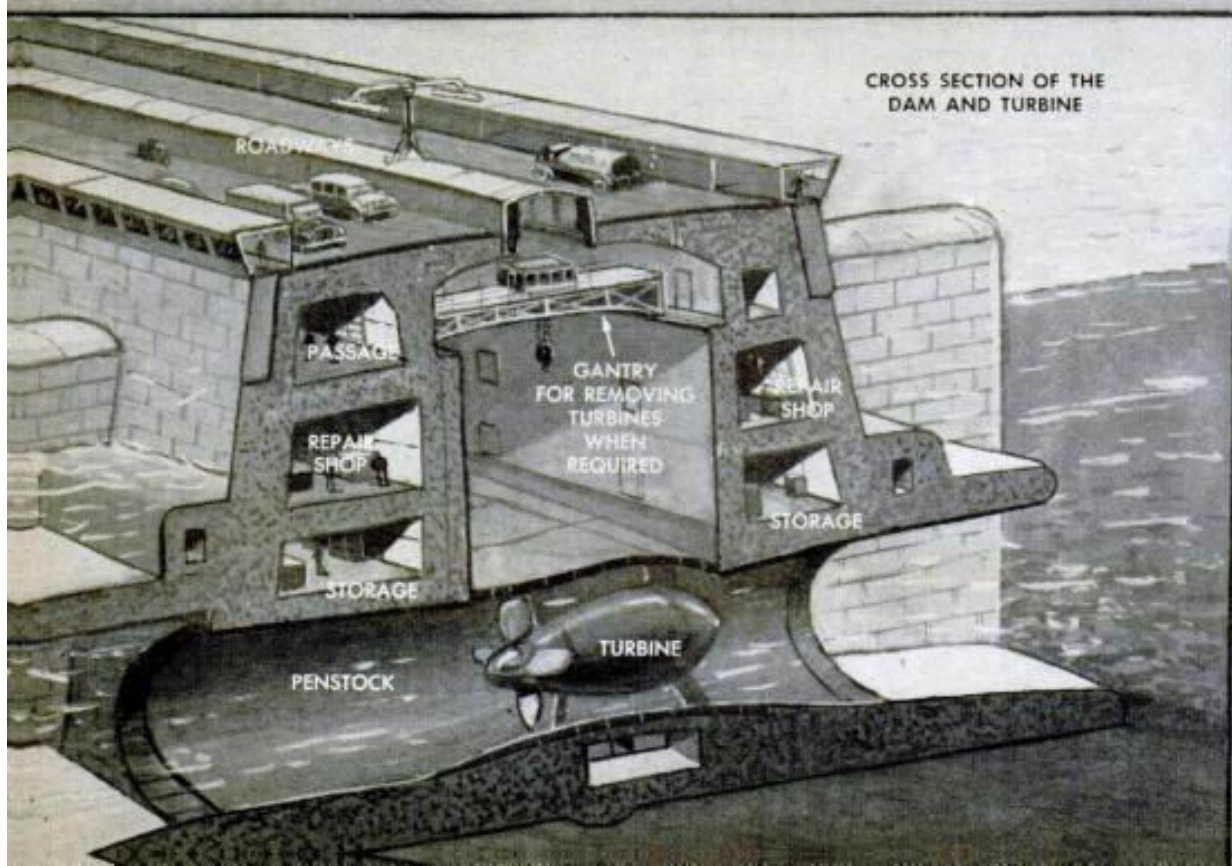
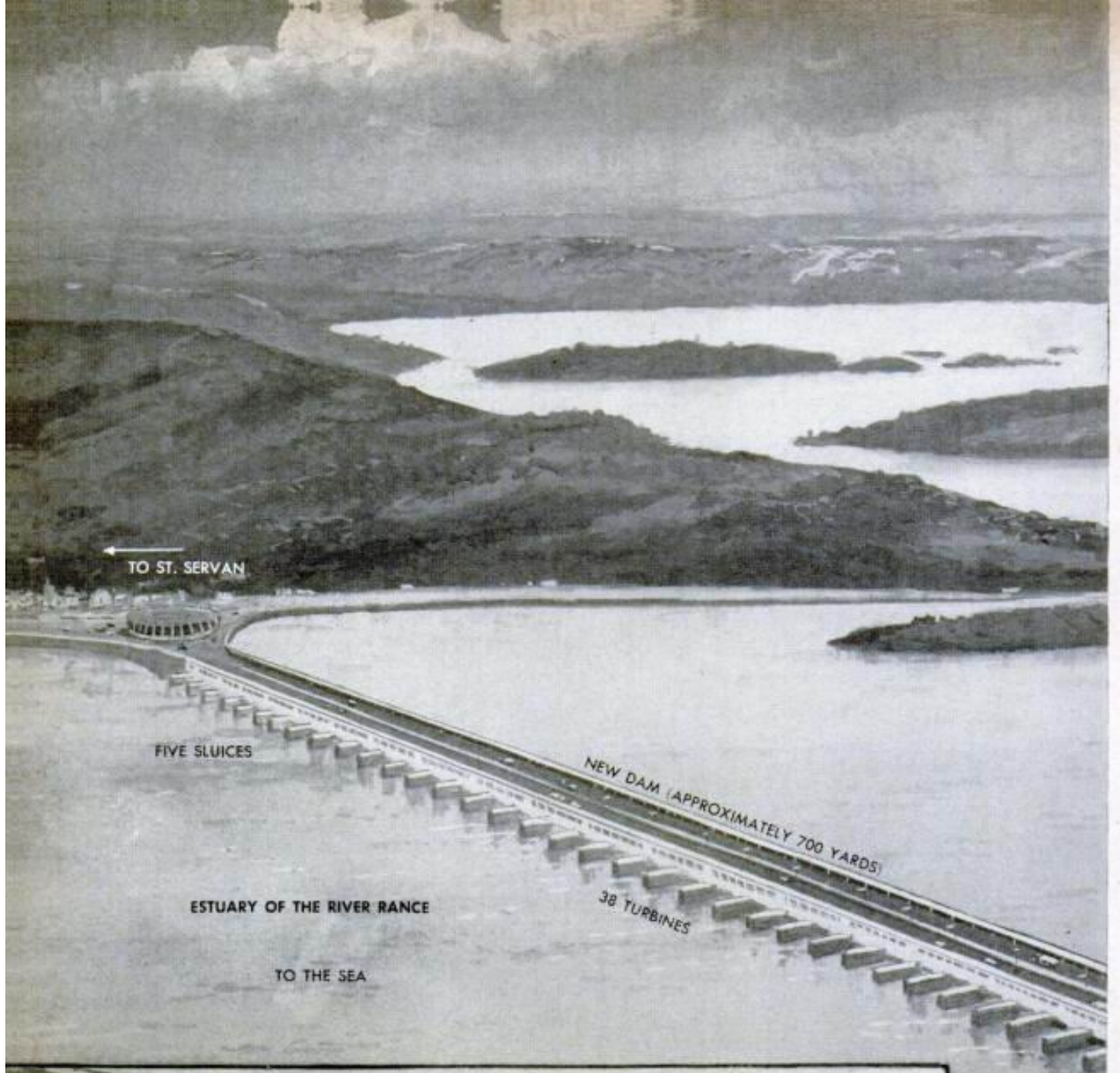
words, a small investment brings big dividends.

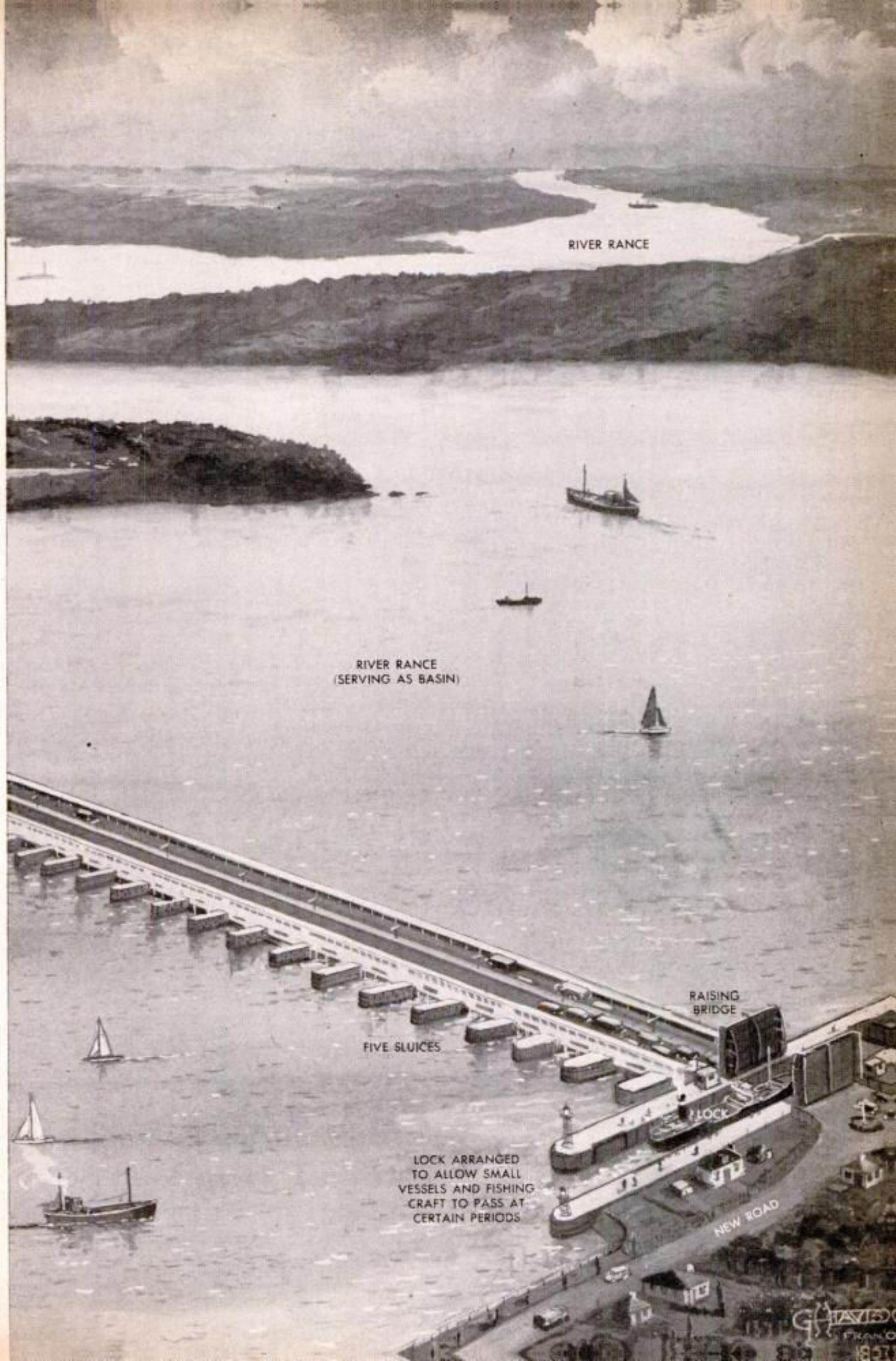
There is one apparent drawback to a tidal-power station if operated in this manner—its intermittent operation. This will not be a great difficulty in connection with the Rance plant because it will run in conjunction with a hydroelectric station. While the tidal station is shut down, the hydrostation will be running at a rate that would exhaust its water reservoir if its operation were to be continuous. When the tidal station is running, the hydrostation will be shut down—thus allowing water to accumulate in its reservoir.

The power station itself will be housed in a tunnel inside the dam. In order to preserve the beauty of the Breton vacation area, the top of the dam will be only a few feet above level of highest tides.

Several complex plans for the type and arrangement of turbines best suited to the situation have been considered and discarded by France's National Electricity Company. The present approved scheme calls for horizontal-axis turbines. This type permits using the units either as turbines or pumps. This offers many opportunities for choosing the best levels for greatest efficiency in operation.

The big advantage of a tidal-power station is that come what may, drought or fuel shortage, it will never lack water for its operation. Engineers say it will take about eight years to build the dam. ★ ★ ★





RIVER RANCE

RIVER RANCE
(SERVING AS BASIN)

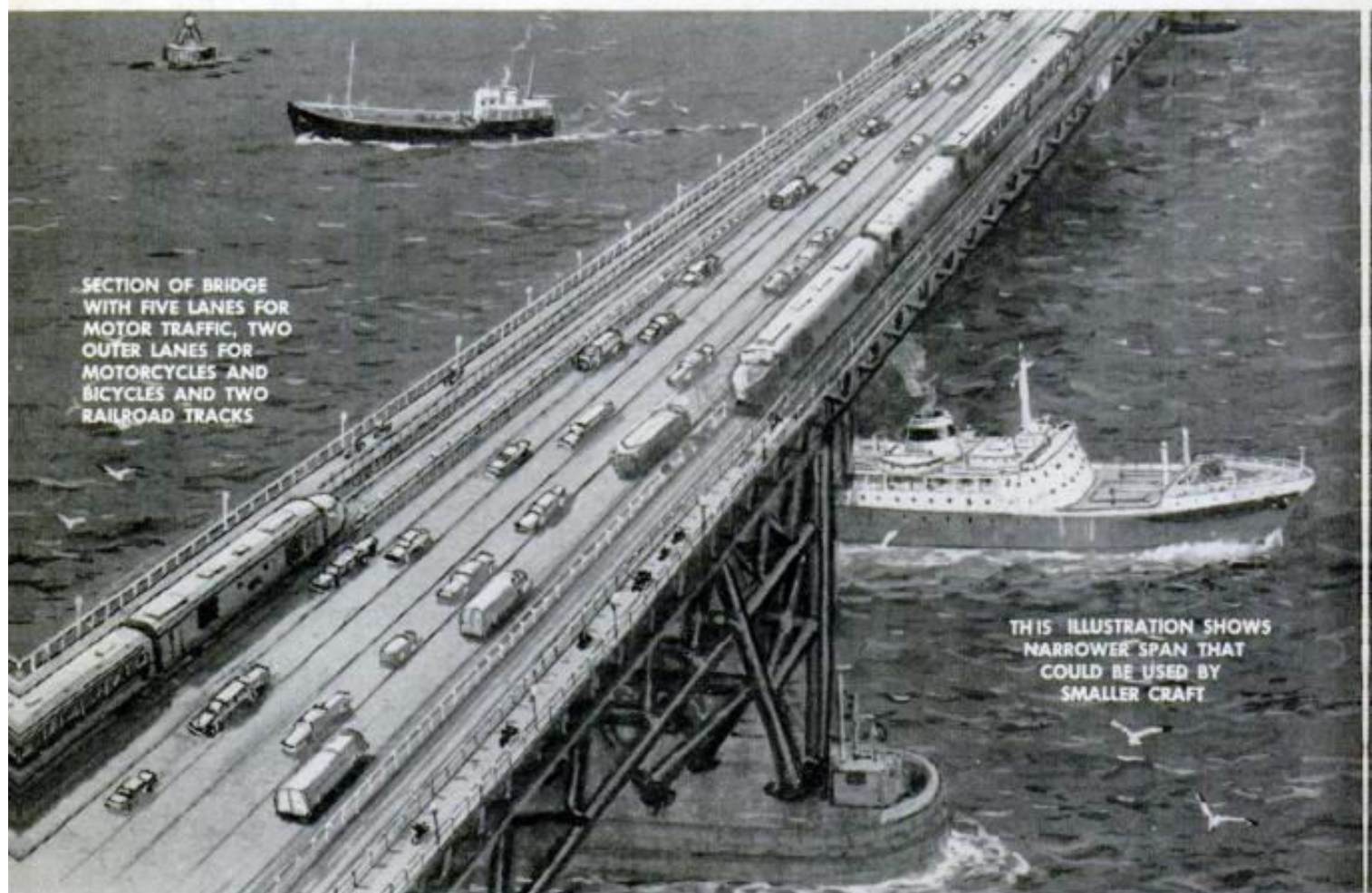
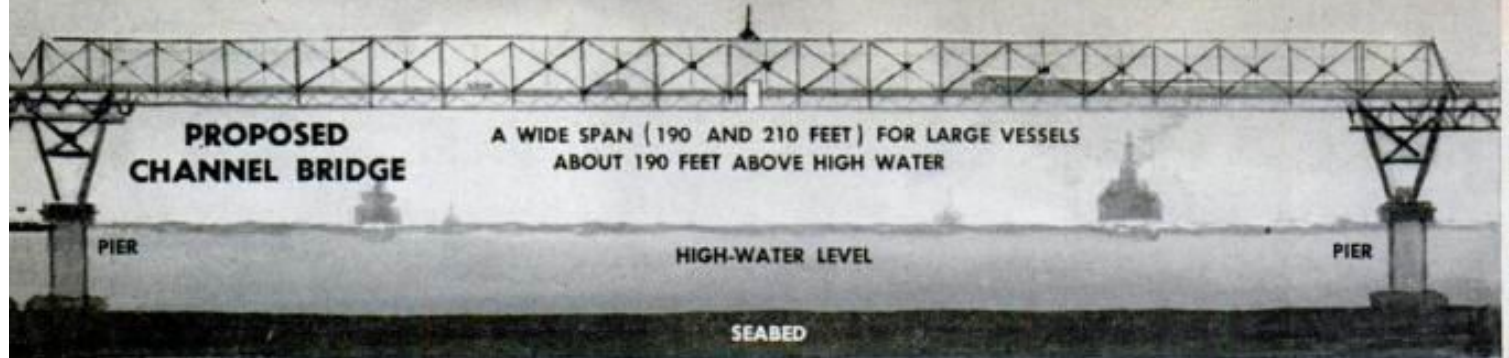
FIVE SLUICES

RAISING
BRIDGE

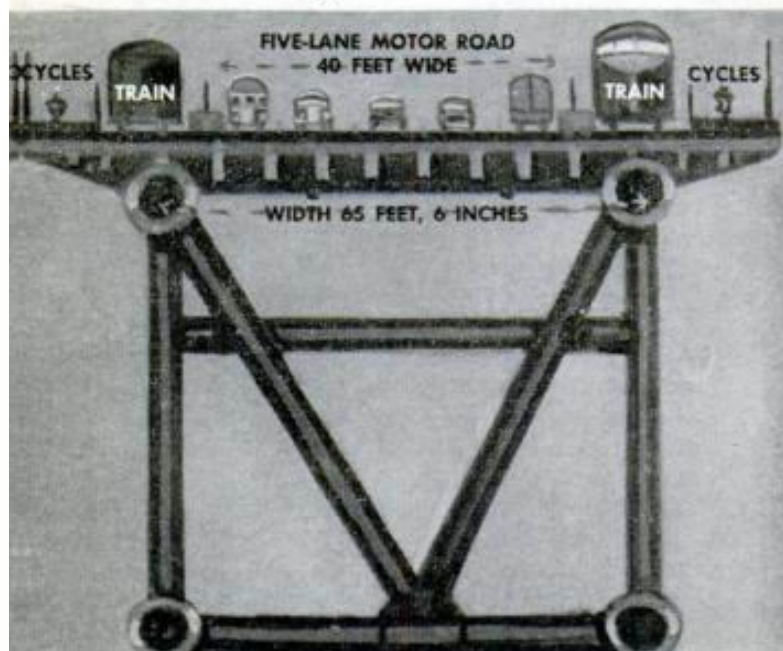
LOCK

LOCK ARRANGED
TO ALLOW SMALL
VESSELS AND FISHING
CRAFT TO PASS AT
CERTAIN PERIODS

NEW ROAD



Bridge or Tunnel Across the Channel?

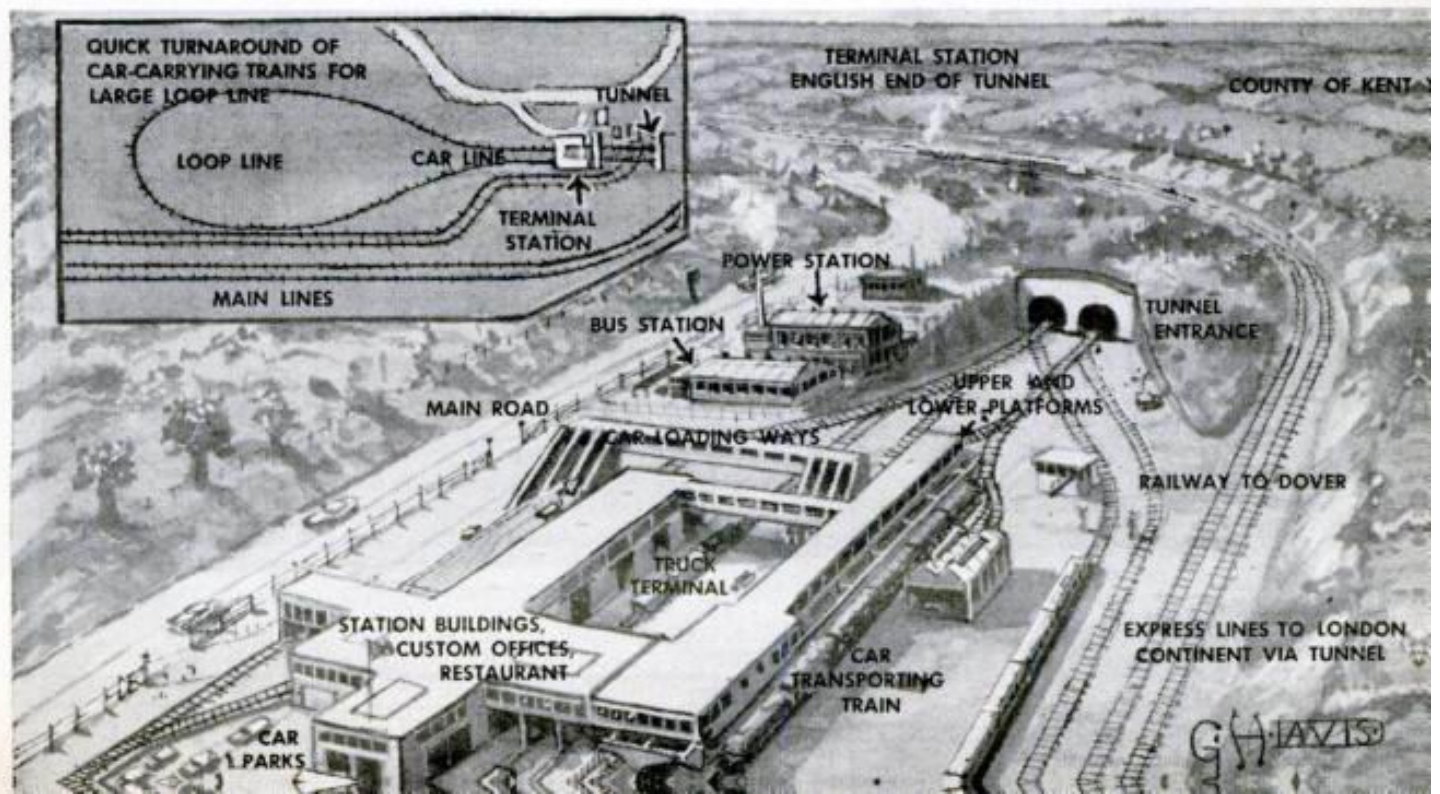
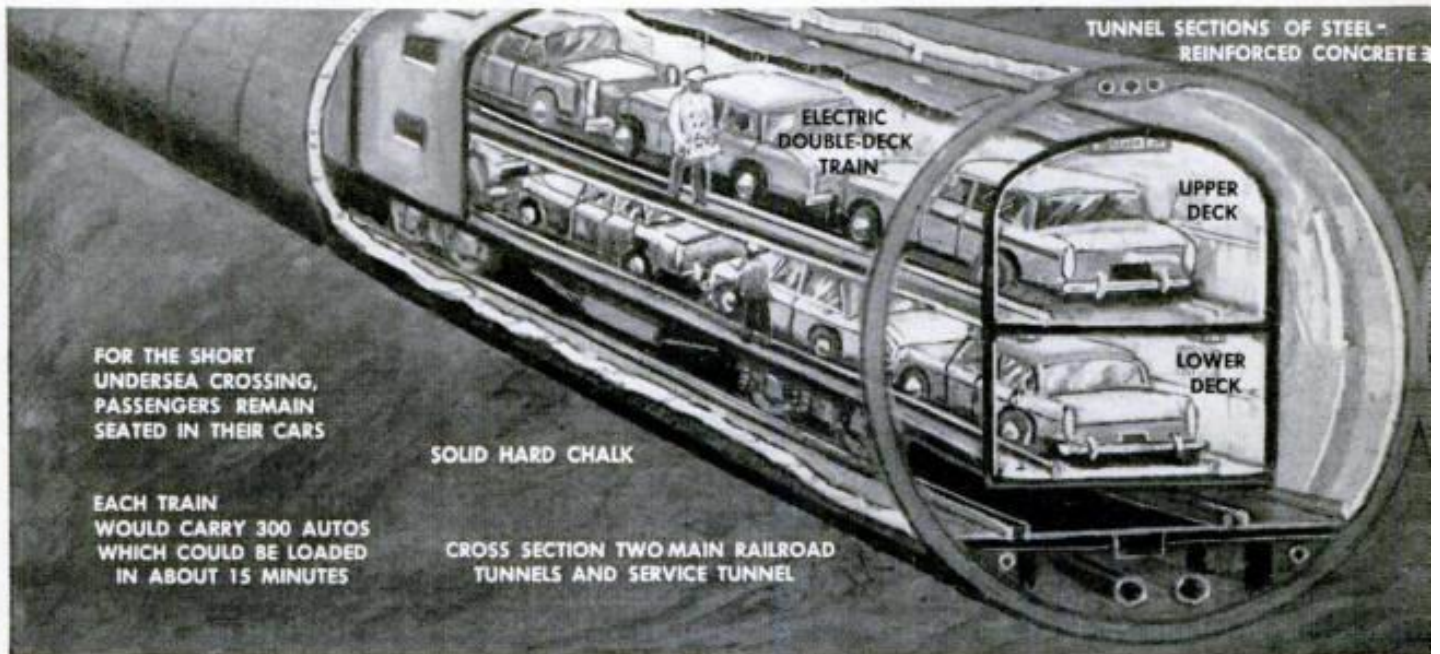
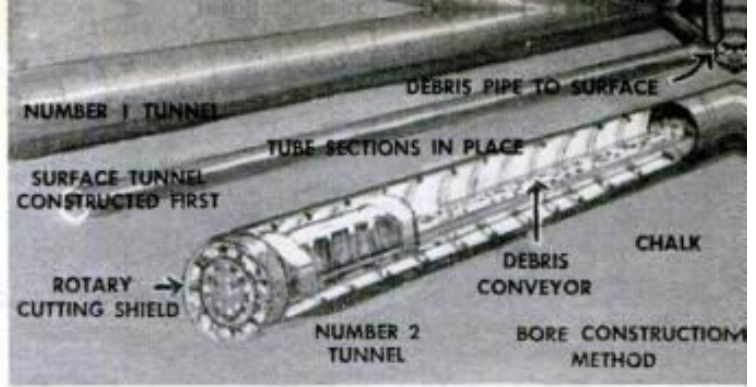
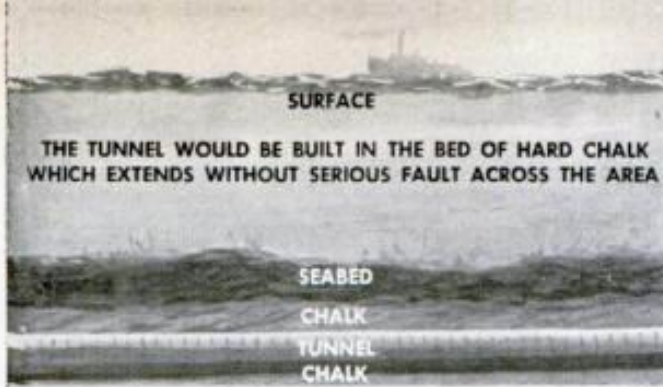


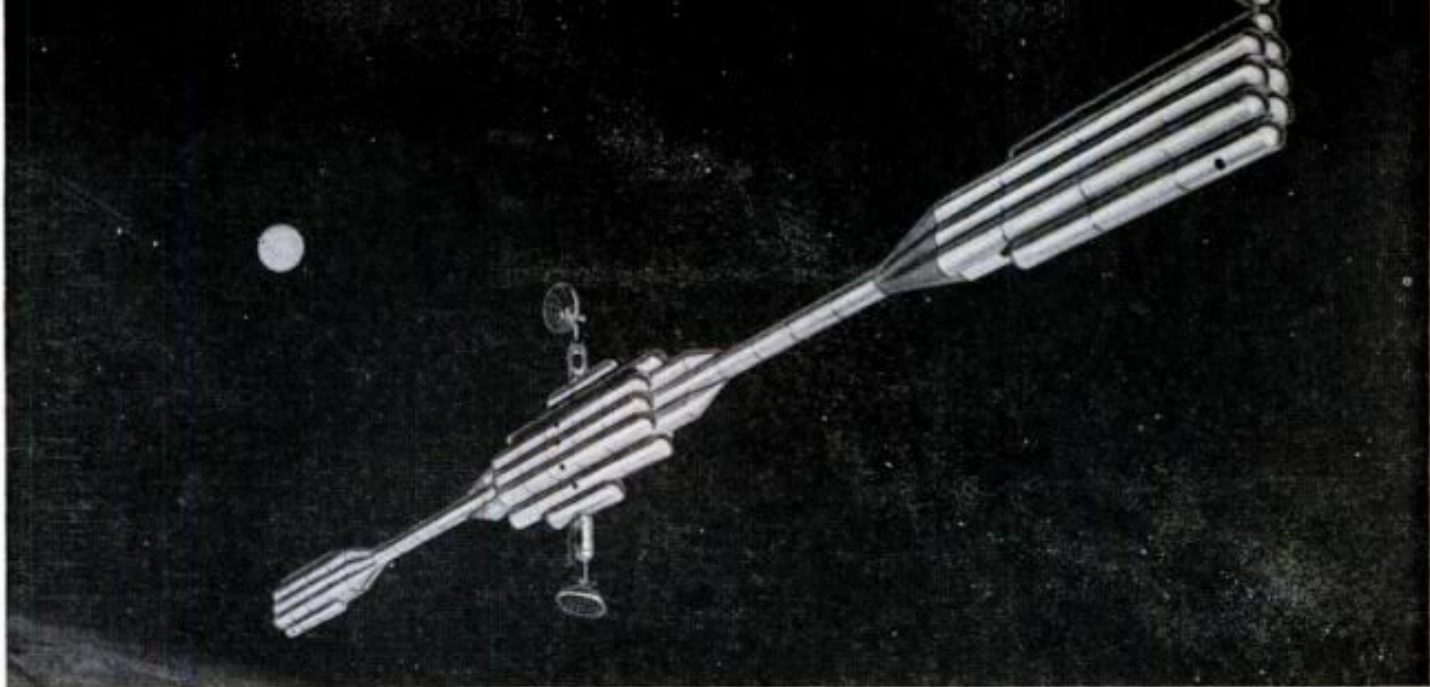
FINAL ARGUMENTS are being given in the 100-year-long debate about whether a tunnel should be drilled under the English Channel to link England and France. Yes, say many, and offer a plan. Good idea, say others, but let's make it a bridge.

Five years from now, claim tunnelers, 60-mile-an-hour electric trains could carry 300 automobiles each through two tunnels. Trains would load in 15 minutes, unload in 10. Cost: \$364,000,000.

But, say bridgers, for \$560,000,000 we could build the bridge and keep in tune with the automobile age: Five lanes for cars, two for cycles, and two railroad tracks.

Text and illustrations by G. H. Davis





Dumbbell-shaped satellite envisioned by Ehricke would have a crew. Rotation would create artificial gravity

WHAT'S THIS RUMOR about Convair getting into the space-flight business? Is it true?" a friend recently asked Krafft A. Ehricke, chief of preliminary design of Convair's astronautics division.

"It certainly is," Ehricke told him. "We are studying advanced instrument satellites and are thinking about space ships that could travel to the moon. And we are considering the sun as a source of power for space propulsion."

Convair is one of the giants of the aviation industry; what is it doing in a field that sounds like science fiction? Why does it have a \$40,000,000 astronautics division?

One reason is that the company is building the "Atlas" intercontinental ballistic missile. This long-range weapon is designed

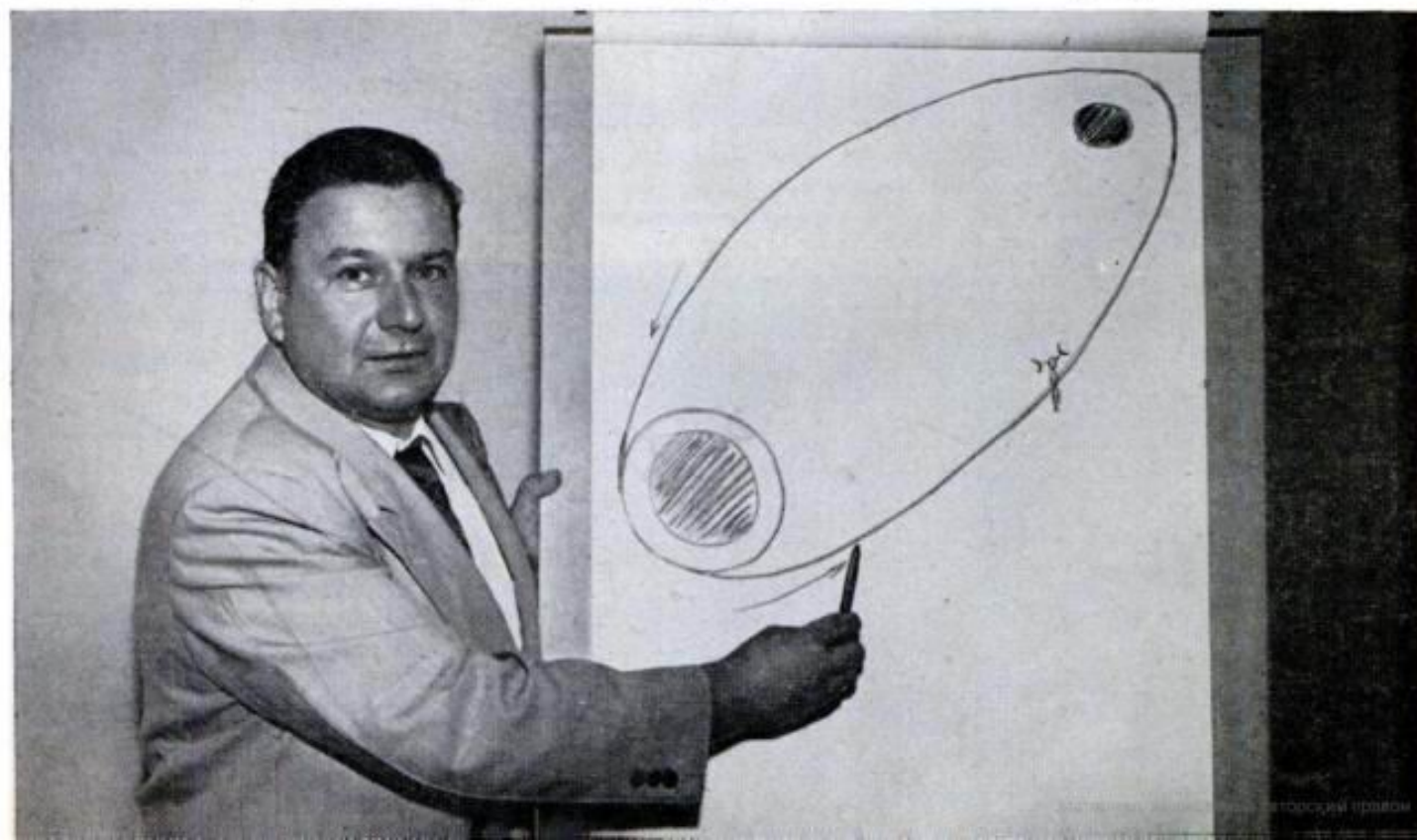
to fly a quarter of the way around the earth in half an hour. En route it will climb some 500 miles above the surface and for a time will be a true space vehicle. Everything that can be learned about conditions in space is affecting the design of the ICBM.

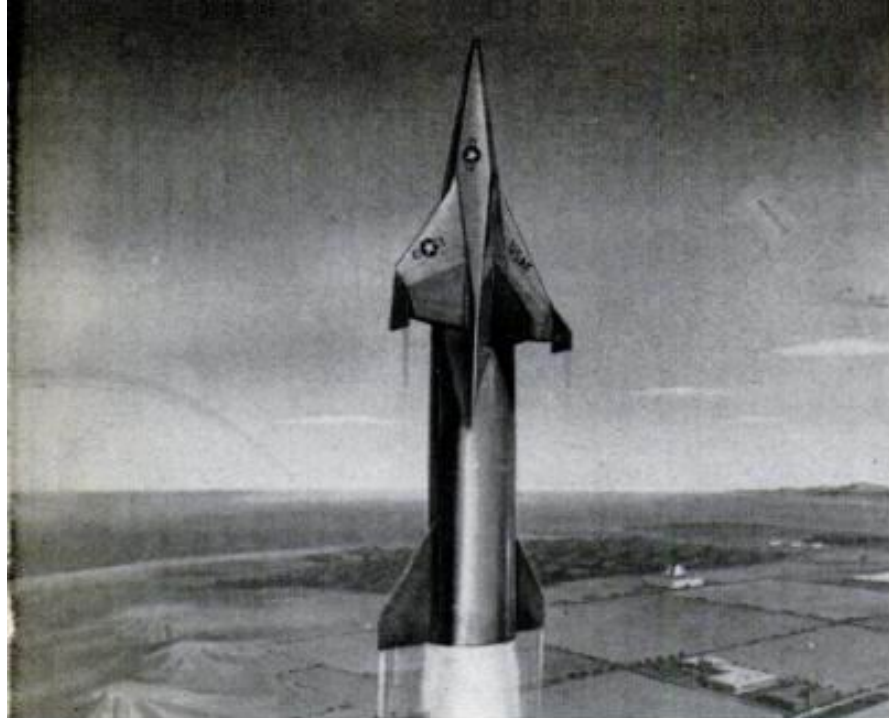
Ballistic Missile

The Atlas is known as a ballistic missile because its trajectory is like that of an artillery shell. It can be guided only during the time its rocket motors are blasting. During the rest of the missile's flight its trajectory is governed by the known laws of ballistics plus a number of new factors such as the effect of the virtual vacuum at extremely high altitude.

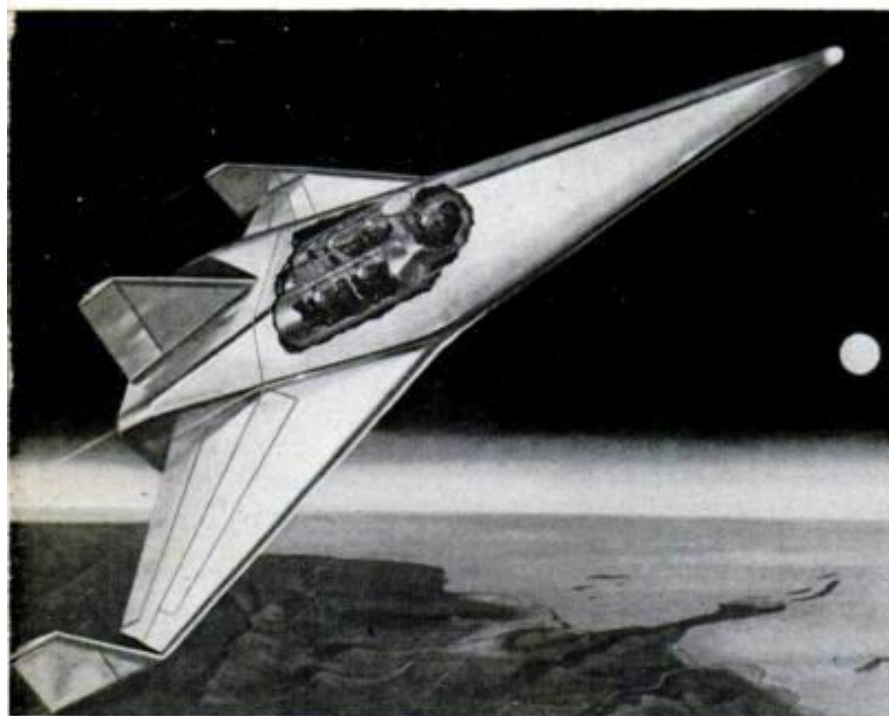
The ICBM has been called the ultimate

Ehricke shows how space ship for circling moon would actually be an earth satellite on long elliptical orbit





Shuttle craft would transport personnel to satellite at 600-mile altitude. Lower rocket portion detaches after take-off



During the return trip, craft stalls with nose high as it settles into dense atmosphere. Pointed nose glows from aerodynamic heat. Below, should anything go wrong, power section could be detached and the craft flown to earth as a glider



weapon. It is designed to carry a thermonuclear warhead that is at least 100 times more destructive than an ordinary atom bomb. Once launched, it is believed to be unstoppable—unlike the winged cruise missiles that are powered with jets or ramjets and that fly at aircraft altitudes and at speeds of around Mach 2. The Atlas will have a hypersonic speed of about Mach 20, some 15,000 miles per hour.

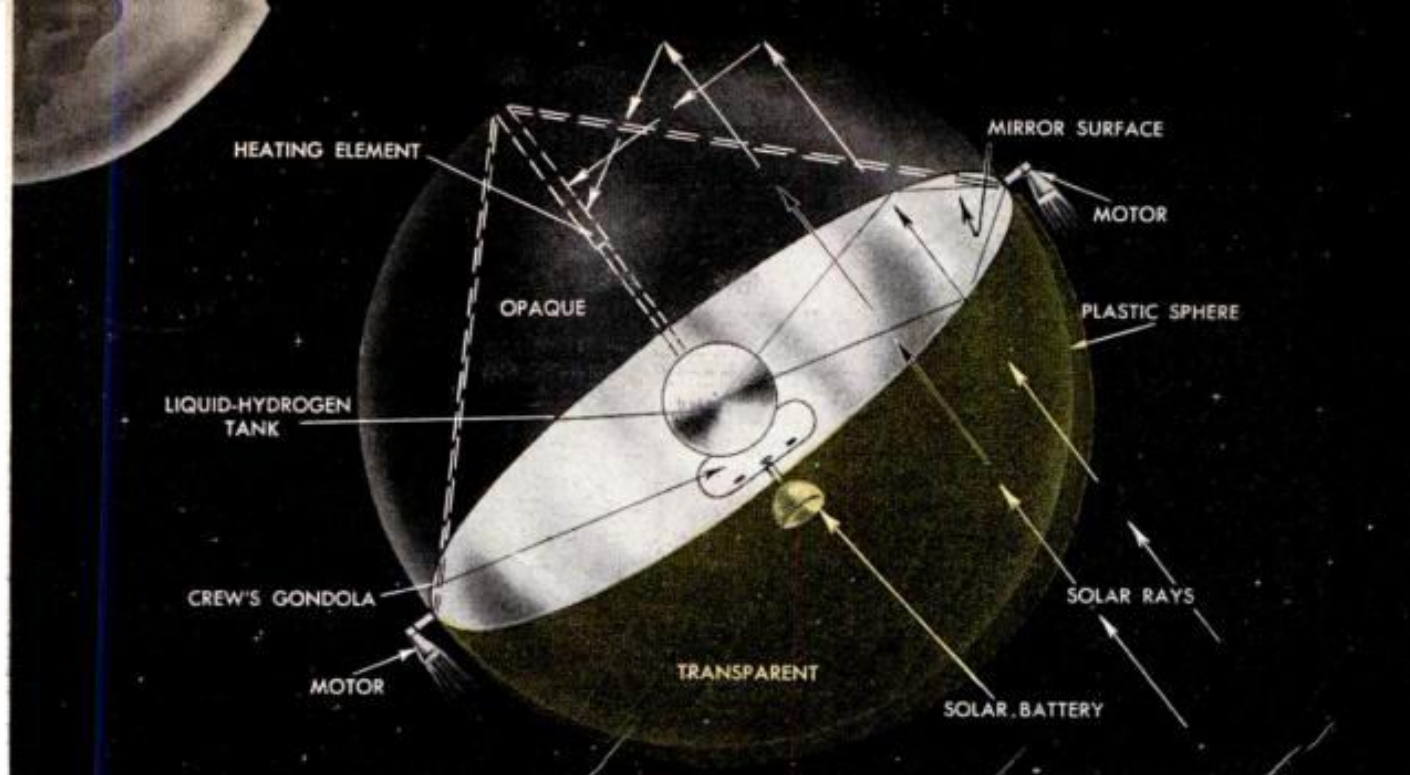
Some perplexing problems must be solved before the first of these multistep rockets is tested. One concerns guidance. During the half hour that the missile is flying, its target will have moved some 500 miles because of the rotation of the earth. If the missile is fired toward the west, the target will move 500 miles toward it during the time the missile is in the air. If the missile is fired in an easterly direction, the target will travel 500 miles away during the half hour. Automatic controls for cutting off the rocket motors at precisely the right times must be adjusted to compensate for the direction in which the missile is fired.

Another problem is that of getting the missile back down through the atmosphere intact. During the plunge to earth its nose will heat up to 5000 degrees and will glow like a meteor. The rocket could disintegrate if the nose melted or if it broke up under thermal stress. It might even ignite with the oxygen in the atmosphere and burn. To prevent any such occurrence the engineers must, in effect, design a better meteor.

One solution they have considered is a very thick nose cone. The molten metal on the surface of the nose would stream away, carrying the heat with it. The rest of the structure would remain relatively cool. Another possibility is some kind of insulation between the outer skin and the warhead itself.

Heat Affects the Air

Even the air that surrounds the missile during its plunge is affected by the heat. The molecules of air collide with so much energy that some of them are broken down into atomic form. The missile is actually surrounded by a new gas, and this could influence its trajectory.



Ehricke suggests space ship made of huge plastic bubble. Solar rays would heat liquid hydrogen to power craft

The whole re-entry problem is so vast that many agencies are studying it. The National Advisory Committee for Aeronautics, for instance, is working with a "light gas" gun in which compressed helium is used to shoot $\frac{1}{4}$ -inch projectiles at speeds of up to 10,000 miles per hour. When fired into the open air these projectiles burn white-hot from friction with the atmosphere. A larger gun now being built will propel $\frac{3}{4}$ -inch projectiles at a speed of 16,000 miles per hour. This speed will be made inside a flight-test chamber where the atmospheric density can be varied to simulate successive portions of a missile's re-entry through the atmosphere.

Space-flight studies are aiding in the design of the Atlas and, in turn, research on the long-range missile is helping solve some of the problems of space vehicles. The small terrestrial satellites to be launched in the next 18 months are only the forerunners of the larger satellites that will follow.

Already contemplated are noninhabited instrument satellites that will be as large as an ordinary room. These will be sent around the earth on long elliptical orbits. They will carry instruments to measure such quantities as magnetic fields in space, pressures, temperatures and the different kinds of solar radiation. All this information will be transmitted to earth by radio.

The Moon on Television

Kraft Ehricke and his fellow engineers expect that large modified instrument satellites will be able to swing close to the moon, including its other side, and will be able to transmit close-up views of the lunar surfaces to earth by television.

"Eventually noninhabited vehicles will be sent far out into interplanetary space," Ehricke predicts. "There the distances are so vast that tracking them is going to be difficult. One idea is to equip such a vehicle with a few small A-bombs that would be released and detonated at regular intervals.

Diagram shows suggested zones for various satellites, and altitudes and ranges of existing or proposed missiles

